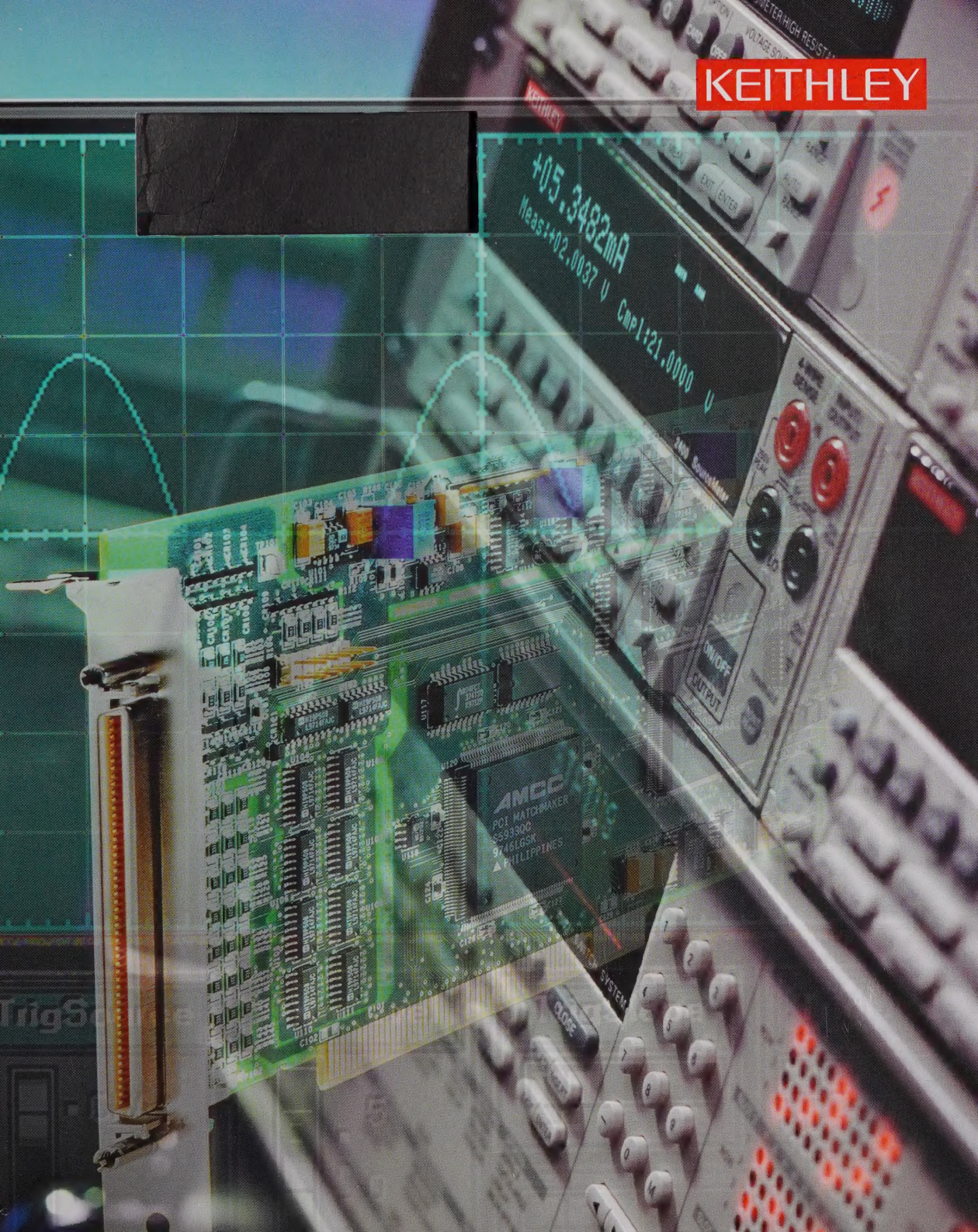
KEITHLEY
+05.3482mA
Meas:+02.0037 V
Cmp1:21.0000 V
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Model 2700 Multimeter/ Data Acquisition System

User's Manual

Contains Operating and Programming Information

KEITHLEY

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10/99

2700 Series Multimeter/Data Acquisition System
User's Manual

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All Keithley product names are trademarks or registered trademarks of Keithley Instruments, Inc.
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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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1
Getting Started

- **General information** — Covers general information that includes warranty information, contact information, safety symbols and terms, inspection, and available options and accessories.
- **Model 2700 features** — Summarizes the features of Model 2700.
- **Plug-in switching modules** — Summarizes the capabilities of the Keithley Model 7700 series switching modules.
- **Front and rear panel familiarization** — Summarizes the controls and connectors of the instrument.
- **Power-up** — Covers line power connection, line voltage setting, fuse replacement, power line frequency, and the power-up sequence.
- **Display** — Provides information about the display of Model 2700.
- **Defaults and user setups** — Lists the *RST and factory default settings, and covers the four setup configurations available to the user.
- **Remote programming information** — Explains how SCPI commands are presented in this manual.

General information

Warranty information

Warranty information is located at the front of this manual. Should your Model 2700 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the instrument for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

Contact information

Worldwide phone numbers are listed at the front of this manual. If you have any questions, please contact your local Keithley representative or call a Keithley Application Engineer at 1-800-348-3735 (U.S. and Canada only).

Safety symbols and terms

The following symbols and terms may be found on the instrument or used in this manual:

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on the instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Inspection

Model 2700 was carefully inspected electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. (There may be a protective film over the display lens, which can be removed). Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment. The following items are included with every Model 2700 order:

- Model 2700 with line cord
- Safety test leads (Model 1751)
- Accessories as ordered
- Certificate of calibration
- Model 2700 User's Manual (P/N 2700-900-00)
- Model 2700 Service Manual (P/N 2700-902-00)
- Manual Addenda (pertains to any improvements or changes concerning the instrument or manual)

If an additional manual is required, order the appropriate manual package. The manual packages include a manual and any pertinent addenda.

Options and accessories

Plug-in switching modules

NOTE *Table 1-1 provides side-by-side comparison of the following Keithley switching modules.*

Model 7700 — This differential multiplexer provides 20 channels of 2-pole input, or 10 channels of 4-pole input. The internal cold junction allows direct-connection of thermocouples. Also has two 2-pole channels used exclusively for current input.

Model 7702 — This differential multiplexer provides 40 channels of 2-pole input, or 20 channels of 4-pole input. Also has two 2-pole channels used exclusively for current input.

Model 7703 — This differential multiplexer provides 32 channels of 2-pole input, or 16 channels of 4-pole input.

Model 7705 — This control module provides 40 1-pole switching channels for multi-close operation.

Model 7706 — This all-in-one module provides 20/10 channels of 2/4-pole input, 16 digital outputs, two analog outputs, one 32-bit counter with gating and totalizer.

Test leads and connector adapter

Model 7788 DB-50 connector kit — Contains two male DB-50 connectors. These connectors mate to the female connectors of the Models 7703 and 7705 switching modules.

Cables and adapters (GPIB and trigger link)

Models 7007-1 and 7007-2 shielded GPIB cables — Connect Model 2700 to the GPIB bus using shielded cables and connectors to reduce electromagnetic interference (EMI). Model 7007-1 is one meter long; Model 7007-2 is two meters long.

Models 8501-1 and 8501-2 trigger link cables — Connect Model 2700 to other instruments with Trigger Link connectors (e.g., Model 7002 Switch System). Model 8501-1 is one meter long; Model 8501-2 is two meters long.

Model 8502 trigger link adapter — Lets you connect any of the six trigger link lines of Model 2700 to instruments that use the standard BNC trigger connectors.

Model 8503 DIN to BNC trigger cable — Lets you connect trigger link lines one (Voltmeter Complete) and two (External Trigger) of Model 2700 to instruments that use BNC trigger connectors. Model 8503 is one meter long.

Rack mount kits

Model 4288-1 single fixed rack mount kit — Mounts a single Model 2700 in a standard 19-inch rack.

Model 4288-2 side-by-side rack mount kit — Mounts two instruments (Models 182, 428, 486, 487, 2000, 2001, 2002, 2010, 2400, 2410, 2420, 2430, 6430, 2700, 6517A, 7001) side-by-side in a standard 19-inch rack.

Model 4288-4 side-by-side rack mount kit — Mounts Model 2700 and a 5.25-inch instrument (Models 195A, 196, 220, 224, 230, 263, 595, 614, 617, 705, 740, 775A, 6512) side-by-side in a standard 19-inch rack.

Carrying case

Model 1050 padded carrying case — A carrying case for the Model 2700. Includes handles and shoulder strap.

Model 2700 features

Model 2700 is a 6½-digit high-performance multimeter/data acquisition system. It can measure voltage (DC and AC), current (DC and AC), resistance (2- and 4-wire), temperature (thermocouple, thermistor and 4-wire RTD), frequency and period, and test continuity.

The Model 2700 has two slots that will accommodate Keithley Model 7700 series switching modules (see Table 1-1). Each channel of a switching module that is closed or scanned is measured by the Model 2700. For scanning, each channel can have its own unique setup (i.e., function, range, digits, etc.).

More information on its measurement capabilities and an overview of the Model 7700 switching module are explained in Section 2 of this manual (see "Basic operation overview"). Specifications for the Model 2700 and all the switching modules are provided in Appendix A.

Additional features of Model 2700 include:

- **Setup storage** — Six instrument setups (four user, *RST defaults and factory defaults) can be saved and recalled.
- **Offset compensated ohms** — A two-measurement process for 4-wire ohms to cancel the effects of thermal EMFs.
- **Math** — mX+b and percent calculations provide mathematical manipulation of readings.
- **Relative** — Null offsets or establish baseline values.
- **Ratio and channel average** — Ratio and average calculations for two switching module channels.
- **Buffer** — Store up to 55,000 readings in the internal buffer.
- **Limits** — Two sets of high and low reading limits to test devices.
- **Digital I/O port** — Five digital limit test output lines to control external circuitry. Trigger link input can also be accessed at this port.
- **Monitor** — The Model 2700 can monitor a selected channel. A scan can be triggered to start when the Monitor detects a reached reading limit.
- **Remote interface** — Model 2700 can be controlled using the IEEE-488 interface (GPIB) or the RS-232 interface.

Plug-in switching modules

Up to two Keithley Model 7700 switching modules can be installed in the Model 2700. A side-by-side comparison of the switching modules is provided in Table 1-1.

Detailed operating information for the Model 7700 switching module is provided in Section 2 (see "Model 7700 switching module"). Details on the other switching modules are provided in the appendices.

Table 1-1
Model 7700 series switching modules

	Model 7700	Model 7702	Model 7703	Model 7705	Model 7706
2-pole operation	20 channels	40 channels	32 channels	N/A	20 channels
4-pole operation	10 channel pairs	20 channel pairs	16 channel pairs	N/A	10 channel pairs
1-pole operation	N/A	N/A	N/A	40 channels	N/A
Measure volts	300V Max	300V Max	300V Max	300V Max	300V Max
Measure amps	Ch 21 and 22, 3A Max	Ch 41 and 42, 3A Max	No	No	No
Measure ohms	2/4-wire	2/4-wire	2/4-wire	No	No
Cold junction for thermocouples	Yes	No	No	No	Yes
Connector type	Screw terminals	Screw terminals	2 female DB-50s	2 female DB-50s	Mini screw terminals
Unique features	All DMM functions	All DMM functions	All DMM functions, reed relays	Multi-close operation	16 digital outputs, 2 analog outputs, one counter, totalizer

Switching module queries

There is a series of SYSTem:CARDx commands that can be used to acquire the following information about the switching module installed in the Model 2700.

- Return the serial number and firmware revision.
- Determine the maximum allowable voltage.
- Determine if the module supports multiplexer or isolated channels.
- Determine if the module has built-in temperature sensors for internal cold junction, thermocouple temperature measurements.
- Determine which channels are used for volts/2-wire measurements and which are used for amps.
- Determine which channels are used for analog or digital output.
- Determine the totalizer channel (Model 7706 only).

The SYSTem:CARDx commands are provided in Table 14-7.

Pseudocards

Using remote programming, you can assign a pseudocard to an empty switching module slot. With a pseudocard "installed," the Model 2700 will operate as if the switching module is installed in the Model 2700. This feature allows you to configure your system without having the actual switching module installed in the unit. There is a pseudocard for every Keithley Model 7700 series switching module.

A pseudocard cannot be "installed" from the front panel. However, once it is "installed" you can take the Model 2700 out of remote and use the front panel. When the instrument is turned off, the pseudocard will be lost (uninstalled).

The *OPT? command can be used to determine which pseudocards (or switching modules) are installed in the Model 2700. For example, assume pseudocard 7700 is "installed" in slot 1, and the Model 7702 switching module is installed in slot 2. After sending *OPT? and addressing the Model 2700 to talk, the following response message will be sent to the computer:

7700, 7702

The commands to "install" pseudocards and read the two slots are listed in Table 1-2.

Table 1-2
Pseudocard commands

Command	Description
:SYSTem:PCARd1 <name>	Select pseudocard for slot 1 (<name> = C7700, C7702, C7703, C7705 or C7706).
:SYSTem:PCARd2 <name>	Select pseudocard for slot 2 (<name> = C7700, C7702, C7703, C7705 or C7706).
*OPT?	Query slots 1 and 2.

Programming example

NOTE *Slot 2 of the Model 2700 must be empty in order to perform the following programming example. You cannot assign a pseudocard to a slot that already has a switching module installed in it.*

The following command sequence sets up the Model 2700 to operate as if a Model 7700 switching module is installed in slot 2:

```
SYSTem:PCAR2 C7700                    ' "Install" pseudocard 7700 for slot 2.
*OPT?                                 ' Query slots 1 and 2.
```

Front and rear panel familiarization

Front panel summary

The front panel of Model 2700 is shown in Figure 1-1.

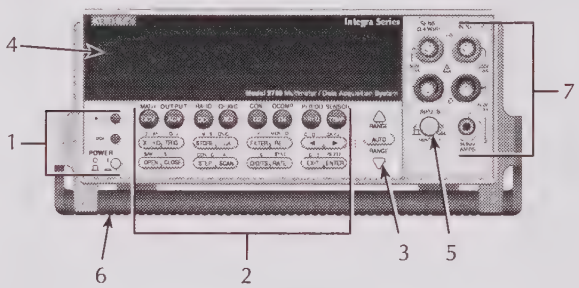


Figure 1-1
Model 2700 front panel

NOTE *Most keys provide a dual function or operation. The nomenclature on a key indicates its unshifted function/operation, which is selected by pressing the key. Nomenclature (in blue) above a key indicates its shifted function. A shifted function is selected by pressing the SHIFT key and then the function/operation key.*

1 Special keys and power switch:

SHIFT	Use to select a shifted function or operation.
LOCAL	Cancels GPIB remote mode.
POWER	Power switch. In position turns 2700 on (I), out position turns it off (O).

2 Function and operation keys:

Top Row

Unshifted

DCV	Selects DC voltage measurement function.
ACV	Selects AC voltage measurement function.
DCI	Selects DC current measurement function.
ACI	Selects AC current measurement function.
Ω2	Selects 2-wire resistance measurement function.
Ω4	Selects 4-wire resistance measurement function.
FREQ	Selects frequency measurement function.
TEMP	Selects temperature measurement function.

Shifted

MATH	Configures and controls mX+b or percent calculation.
OUTPUT	Configures and controls digital and audio (beeper) output for limits.
RATIO	Enables/disables channel ratio.
CH-AVG	Enables/disables channel average.
CONT	Configures and controls continuity test.
OCOMP	Enables/disables offset compensated ohms with Ω4 function selected.
PERIOD	Selects period measurement function.
SENSOR	Configures temperature measurements.

Middle Row

Unshifted

EX TRIG	Selects external triggering (front panel, bus, trigger link) as the trigger source.
TRIG	Triggers a measurement when in external triggering (EX TRIG).
STORE	Sets the number of readings to store and enables the buffer.
RECALL	Displays stored readings and buffer statistics. Use the ◀, ▶, ▲, and ▼ keys to navigate through buffer.
FILTER	Enables/disables filter for selected function.
REL	Enables/disables relative for selected function.
◀ and ▶	Dual function - Manually scans switching channels. When in a menu, these keys control cursor position for making selections or change values.

Shifted

DELAY	Sets user delay between trigger and measurement.
HOLD	Holds reading when the selected number of samples is within the selected tolerance.
LIMITS	Sets upper and lower limits for readings.
ON/OFF	Enables/disables limits.
TYPE	Configures and enables filter for selected function.
MONITOR	Selects and enable/disables monitor channel.
CH-OFF	Disables channel for a scan (must be in scan channel setup mode).
CARD	Identifies switching module(s) installed in mainframe.

Bottom Row

Unshifted

OPEN	Opens closed channel.
CLOSE	Closes specified channel.
STEP	Steps through channels; sends a trigger after each channel.
SCAN	Scans through channels; sends a trigger after last channel.
DIGITS	Sets display resolution for all functions.
RATE	Sets measurement speed (fast, medium, or slow) for all functions.
EXIT	Cancels selection, moves back to measurement display.
ENTER	Accepts selection, moves to next choice or back to measurement display.

Shifted

SAVE	Saves up to four instrument setups for future recall.
SETUP	Restores a default setup (factory or *RST) or recalls a saved setup.
CONFIG	Selects and configures a simple scan or an advanced scan.
HALT	Disables step/scan.
TEST	Selects the calibration menu, display test or the key-press test.
LSYNC	Enables/disables line cycle synchronization. When enabled, noise induced by the power line is reduced at the expense of speed.
GPIB	Enables/disables GPIB and selects address.
RS-232	Enables/disables RS-232 interface; selects baud rate, flow control, and terminator.

3 Range keys:

▲ and ▼	Dual function - Selects the next higher/lower measurement range for the selected function. When in a menu, these keys make selections or change values.
AUTO	Enables/disables autorange for the selected function.

4 Display annunciators:

* (asterisk)	Readings being stored in buffer.
↔ (more)	Indicates additional selections are available.
))) (speaker)	Beeper on for continuity or limits testing.
4W	4-wire resistance or 4-wire RTD temperature reading displayed.
~AC	AC function selected (ACV, ACV, dB, or ACI).
AUTO	Auto range enabled.
BUFFER	Recalling readings stored in buffer.
CHAN	Setup or a reading for a switching channel displayed.
DELTA	Channel average enabled.
ERR	Questionable reading, or invalid cal step.
FAST	Fast reading rate selected.
FILT	Filter enabled for selected function.
HIGH	Reading has reached or exceeded the enabled high limit.
HOLD	2700 in hold mode.
LSTN	Instrument addressed to listen over GPIB.
LOW	Reading has reached or exceeded the enabled low limit.
MATH	mX+b or percent calculation enabled.
MED	Medium reading rate selected.
MON	Monitor channel displayed.
OCOMP	4-wire offset compensated ohms enabled.
RATIO	Channel ratio enabled.
REAR	Front input terminals disconnected.
REL	Relative enabled for selected function.
REM	Instrument in GPIB remote mode.
SCAN	Scanning operation being performed.
SHIFT	Accessing a shifted key.
SLOW	Slow reading rate selected.
SRQ	Service request over GPIB.
STAT	Displaying buffer statistics.
STEP	Stepping operation being performed.
TALK	Instrument addressed to talk over GPIB bus.
TIMER	Timer controlled triggering in use.
TRIG	External triggering selected (trigger link, TRIG key, or GPIB).

5 INPUTs switch:

Use to select front panel inputs (out; F) position, or switching module inputs (in; R) position.

NOTE *For remote programming, the following command queries the INPUTS switch position:*

```
SYSTem:FRSwitch? ' Query INPUTS switch; 0 = rear, 1 = front.
```

6 Handle:

Pull out and rotate to desired position.

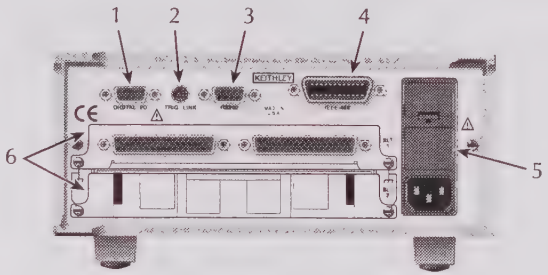
7 Front panel inputs:

INPUT HI and LO	Used for DCV, ACV, Ω2, CONT, FREQ, PERIOD and thermocouple/thermistor TEMP measurements.
AMPS	Use with INPUT LO for DCI and ACI measurements. Also holds current fuse for front panel amps input.
SENSE HI and LO	Use with INPUT HI and LO for Ω4 and RTD TEMP measurements.

Rear panel summary

The rear panel of Model 2700 is shown in Figure 1-2.

Figure 1-2
Model 2700
rear panel



1 DIGITAL I/O

Male DB-9 connector for digital input (trigger link in) and digital outputs.

2 TRIG LINK

Eight-pin micro-DIN connector for sending and receiving trigger pulses among connected instruments. Use a trigger link cable or adapter, such as Models 8501-1, 8501-2, 8502, and 8503.

3 RS-232

Female DB-9 connector for RS-232 operation. Use a straight-through (not null modem) DB-9 shielded cable.

4 IEEE-488

Connector for IEEE-488 (GPIB) operation. Use a shielded cable, such as Models 7007-1 and 7007-2.

5 Power module

Contains the AC line receptacle, power line fuse, and line voltage setting. The instrument can be configured for line voltages of 100V/120V/220V/240VAC at line frequencies of 50 or 60Hz.

6 Slot 1 and Slot 2

Two slots to accommodate Keithley Model 7700 series switching modules.

Power-up

Line power connection

Follow the procedure below to connect the Model 2700 to line power and turn on the instrument.

1. Check to see that the line voltage indicated in the window of the fuse holder assembly (see Figure 1-3) is correct for the operating voltage in your area. If not, refer to the next procedure, "Setting line voltage and replacing fuse."

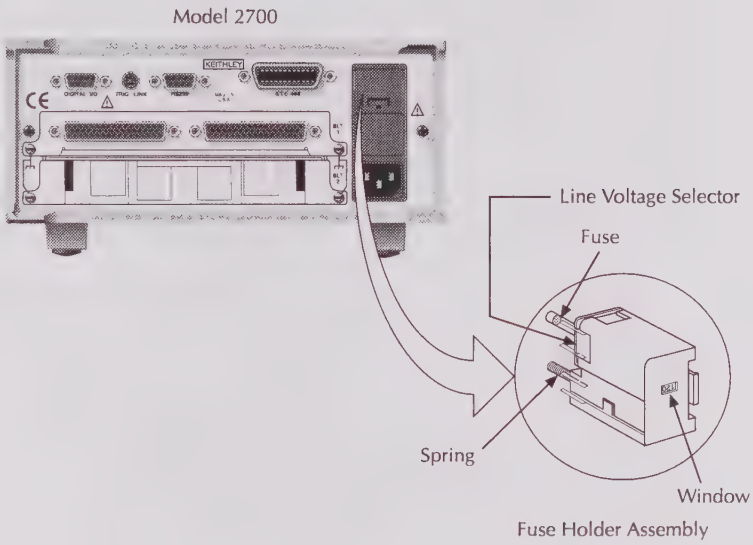
CAUTION **Operating the instrument on an incorrect line voltage may cause damage to the instrument, possibly voiding the warranty.**

2. Before plugging in the power cord, make sure that the front panel power switch is in the off (0) position.
3. Connect the female end of the supplied power cord to the AC receptacle on the rear panel. Connect the other end of the power cord to a grounded AC outlet.

WARNING **The power cord supplied with the Model 2700 contains a separate ground wire for use with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground through the ground wire in the power cord. Failure to use a grounded outlet may result in personal injury or death due to electric shock.**

4. Turn on the instrument by pressing the front panel power switch to the on (1) position.

Figure 1-3
Power module



Line frequency

The Model 2700 will operate at line frequencies from 45Hz to 66Hz, and 360Hz to 440Hz. There are no user-settings for line frequency. It is automatically sensed at power-up. The following command can be used to read the line frequency:

```
SYSTem:LFRequency?                    ' Query power line frequency.
```

Setting line voltage and replacing fuse

A rear panel fuse located next to the AC receptacle protects the power line input of the instrument. If the line voltage setting needs to be changed or the line fuse needs to be replaced, perform the following steps.

WARNING **Make sure the instrument is disconnected from the AC line and other equipment before changing the line voltage setting or replacing the line fuse.**

1. Place the tip of a flat-blade screwdriver into the power module by the fuse holder assembly (see Figure 1-3). Gently push in and up. Release pressure on the assembly and its internal spring will push it out of the power module.

2. Remove the fuse and replace it with the type listed in Table 1-3.

CAUTION **For continued protection against fire or instrument damage, only replace fuse with the type and rating listed. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.**

3. If configuring the instrument for a different line voltage, remove the line voltage selector from the assembly and rotate it to the proper position. When the selector is installed into the fuse holder assembly, the correct line voltage appears sideways in the window.
4. Install the fuse holder assembly into the power module by pushing it in until it locks in place.

Table 1-3
Fuse ratings

Line voltage	Fuse rating	Keithley P/N
100/120V	0.25A slow-blow 5×20mm	FU-96-4
220/240V	0.125A slow-blow 5×20mm	FU-91

Power-up sequence

On power-up, the Model 2700 performs self-tests on its EPROM and RAM and momentarily lights all segments and annunciators. If a failure is detected, the instrument momentarily displays an error message and the ERR annunciator turns on. (Error messages are listed in an appendix).

NOTE *If a problem develops while the instrument is under warranty, return it to Keithley Instruments, Inc., for repair.*

If the instrument passes the self-tests, the firmware revision levels are displayed. An example of this display is:

REV: A01 A02

where: A01 is the main board ROM revision.
A02 is the display board ROM revision.

Installed switching modules are then displayed. For example, if there is a Model 7700 switching module installed in both slots, the following message will be displayed:

1: 7700 2: 7700

If a slot is empty, the message "NONE" will instead be displayed.

If the saved power-on setup is not the factory defaults setup (SYSTem:POSetup PRESet), a message to identify the setup will be briefly displayed (see "Defaults and user setups").

After the power-up sequence, the instrument begins its normal display of readings.

Keyclick

With keyclick enabled, an audible "click" will sound when a front panel key is pressed. Perform the following steps to disable or enable keyclick:

1. Press SHIFT and then LOCAL to display the present state of KEYCLICK (ON or OFF).
2. Press ▲ or ▼ to display the desired keyclick state and press ENTER.

Remote programming

The following command controls keyclick:

```
SYSTem:KCLick <b>                    ' Enable or disable keyclick.
```

where: <b> = ON or OFF

NOTE *Keyclick ON is the FACTORY, *RST, and SYSTem:PRESet default.*

Display

Readings are displayed in engineering units (i.e., 100.23mV), while annunciators indicate various states of operation. See "Front panel summary" (presented earlier in this section) for a complete listing of display annunciators.

NOTE *The display test allows you to test display digit segments and annunciators, and the key test checks the functionality of front panel keys. These tests are accessed by pressing SHIFT and then TEST. Refer to the Model 2700 Service Manual for details.*

Status and error messages

Status and error messages are displayed momentarily. During operation and programming, you will encounter a number of front panel messages. Typical messages are either of status or error variety, as listed in the appendix.

Remote programming - display

Using remote programming, the Model 2700 can display a custom ASCII message (up to 12 characters). Also, the front panel display and controls can be disabled.

Display commands

The commands are listed in Table 1-4. Details on these commands follow the table.

NOTE *Optional command words and queries are not included in Table 1-4. Table 14-1 provides an unabridged list of all display commands.*

Table 1-4
Display commands

Command	Description	Default*
:DISPlay:TEXT:DATA <a>	Define message (<a> = ASCII characters, up to 12).	(none)
:DISPlay:TEXT:STATe <b>	Enable or disable message mode (<b> = ON or OFF).	OFF
:DISPlay:ENABle <b>	Enable or disable the front panel display (<b> = ON or OFF).	OFF

* :SYSTem:PRESet and *RST have no effect on :DISPlay commands. The listed defaults are power-on defaults.

:DISPlay:TEXT:DATA <a> **Define text message**

This command defines the text message for display. A message can be as long as 12 characters. A space counts as a character. Excess message characters results in an error. The characters must be enclosed in either single quotes (' ') or double quotes (" ").

:DISPlay:TEXT:STATe ON | OFF **Control (on/off) message for display**

This command enables and disables the text message mode. When enabled, a defined message is displayed. When disabled, the message is removed from the display.

A user defined text message remains displayed only as long as the instrument is in remote. Taking the instrument out of remote (by pressing the LOCAL key or sending GTL) cancels the message and disables the text message mode.

:DISPlay:ENABle ON | OFF **Control display circuitry**

This command is used to enable and disable the front panel display circuitry. When disabled, the instrument operates at a higher speed. While disabled, the display is frozen.

All front panel controls (except LOCAL) are disabled. Normal display operation can be resumed by using the :ENABle command to enable the display or by putting the Model 2000 into local mode (press LOCAL).

Programming example

The following command sequence displays the text message "TESTING":

```
DISP:TEXT:DATA 'TESTING'              ' Define text message.
DISP:TEXT:STAT ON                     ' Enable text message mode.
```

Defaults and user setups

Model 2700 can be restored to one of six default setup configurations; factory (FACT, *RST) and four user-saved (SAV0, SAV1, SAV2, and SAV3). As shipped from the factory, Model 2700 powers up to the factory (FACT) default settings.

The factory default setup provides continuous triggering, while the *RST default setup places the Model 2700 in the one-shot trigger mode. With one-shot triggering, a measurement is performed whenever the TRIG key is pressed or an initiate command is sent.

The factory and *RST default settings are listed in Table 1-5. The setting differences (Set Diff) between the two default setups are indicated by checkmarks (✓).

NOTE *For remote programming, the SYSTem:PRESet and *RST commands are used to reset the instrument. The *RST command returns the instrument to the *RST defaults and, for the most part, the SYSTem:PRESet command returns the instrument to the factory default conditions. The exceptions are explained as follows:*

*Auto scan and auto channel configuration — Factory defaults disable auto scan and auto channel configuration, while SYSTem:PRESet has no effect. The *RST defaults (front panel and remote operation) have no effect.*

The instrument will power up to whichever default setup is saved as the power-on setup.

NOTE *At the factory, the factory default setup is saved as the SAV0, SAV1, SAV2 and SAV3 setups.*

Saving and restoring setups

Saving a user setup

1. Configure Model 2700 for the desired measurement application.
2. Press SHIFT and then SAVE to access the save setup menu.
3. Press ▶ to place the cursor on the present setup (SAV0, SAV1, SAV2, SAV3).
4. Use the ▲ or ▼ key to display the desired setup and press ENTER. The instrument returns to the normal measurement state.

Saving a power-on setup

1. Configure Model 2700 for the desired measurement application.
2. Press SHIFT and then SAVE to access the save setup menu.
3. Press the ▲ key to display the present power-on (PWR-ON) setup; FACT, *RST, SAV0, SAV1, SAV2, SAV3).
4. Press ▶ to place the cursor on the present power-on setup.
5. Use the ▲ or ▼ key to display the desired setup and press ENTER. The instrument returns to the normal measurement state.

Restoring a setup

1. Press SHIFT and then SETUP to access the restore setup menu.
2. Press ▶ to place the cursor on the present RESTORE setup (FACT, *RST, SAV0, SAV1, SAV2, SAV3).
3. Use the ▲ or ▼ key to display the desired setup and press ENTER. The instrument returns to the normal measurement state.

NOTE *If the settings for a user setup or power-on setup do not match the switching module types presently installed in the Model 2700, error +520 (Saved setup scancard mismatch) occurs when the setup is recalled. The scan list will reset to the factory defaults. However, the saved setup is still retained in memory and can be restored when the matching switching module is later installed.*

Table 1-5
Default settings

Setting	Factory	*RST	Set Diff
Auto channel configuration	No (off)	No effect	✓
Autozero	On	On	
Buffer	No effect	No effect	
Auto clear	No effect	No effect	✓
Channel Average	Off	Off	
Closed channels	None	None	
Continuity			
Beeper	On	On	
Digits	4½ digits	4½ digits	
Range	1kΩ	1kΩ	
Rate	Fast (0.1 PLC)	Fast (0.1 PLC)	
Threshold level	10Ω	10Ω	
Current (AC and DC)			
Bandwidth (AC)	30	30	
Digits (AC)	5½ digits	5½ digits	
Digits (DC)	6½ digits	6½ digits	
Filter	On	Off	✓
Window	0.1%	0.1%	
Count	10	10	
Type	Moving	Repeat	✓
Range	Auto	Auto	
Rate (DC)	Slow (5 PLC)	Slow (5 PLC)	
Rel	Off	Off	
Frequency and Period			
Digits	6½ digits	6½ digits	
Range	10V	10V	
Rate (aperture)	1 second	1 second	
Rel	Off	Off	
Function	DCV		
GPIB	No effect	No effect	
Address	No effect (16 at factory)	No effect (16 at factory)	
Keyclick	On	On	
Limits	Off	Off	
LO Limit 1	-1	-1	
HI Limit 1	+1	+1	
LO Limit 2	-2	-2	
HI Limit 2	+2	+2	
Line Synchronization	Off	Off	
Math			
mX+B	Off	Off	
Scale Factor	1.0	1.0	
Offset	0.0	0.0	
Units	"X"	"X"	
Percent	Off	Off	
Reference	1.0	1.0	
Monitor	Off	Off	
Output			
Beeper	Never	Never	
Digital Output	Off	Off	
Logic Sense	High	High	
Pulse	No (off)	No (off)	
Ratio	Off	Off	

Table 1-5 (Continued)
Default settings

Setting	Factory	*RST	Set Diff
Resistance (Ω2 and Ω4)			
Digits	6½ digits	6½ digits	
Filter	On	Off	✓
Window	0.1%	0.1%	
Count	10	10	
Type	Moving	Repeat	✓
Offset compensation (OCOMP)	Off	Off	
Range	Auto	Auto	
Rate	Slow (5 PLC)	Slow (5 PLC)	
Rel	Off	Off	
RS-232	Off	Off	
Baud rate	No effect	No effect	
Flow control	XonXoFF	XonXoFF	
Terminator	No effect	No effect	
Scanning	Disabled	Disabled	
Auto scan	No (off)	No effect	✓
Type (Simple or Advanced)	No effect	No effect	
Simple scan			
Minimum channel	101 or 201	101 or 201	
Maximum channel	No effect	No effect	
Timer	Off	Off	
Reading count	No effect	No effect	
Advanced scan			
Setup	No effect	No effect	
Immediate trigger	On	On	
Limit triggers	Off	Off	
Timer	Off	Off	
Reading count	No effect	No effect	
Temperature			
Digits	5½ digits	5½ digits	
Filter	On	Off	✓
Window	0.1%	0.1%	
Count	10	10	
Type	Moving	Repeat	✓
Rate	Slow (5 PLC)	Slow (5 PLC)	
Rel	Off	Off	
Sensor	Thermocouple	Thermocouple	
Junction	Simulated (23°C)	Simulated (23°C)	
Open detector	No (off)	No (off)	
Type	K	K	
Units	°C	°C	
Timestamp	No effect	No effect	
Triggering	Continuous	One-shot	✓
Delay	Auto	Auto	
Source	Immediate	Immediate	
Voltage (AC and DC)			
dB	Off	Off	
Reference	1.0	1.0	
Digits (AC)	5½ digits	5½ digits	
Digits (DC)	6½ digits	6½ digits	

Table 1-5 (Continued)
Default settings

Setting	Factory	*RST	Set Diff
Filter	On	Off	✓
Window	0.1%	0.1%	
Count	10	10	
Type	Moving	Repeat	✓
Range	Auto	Auto	
Rate (DC)	Slow (5 PLC)	Slow (5 PLC)	
Rel	Off	Off	

Remote programming - default and user setups

Default and user setup commands are listed in Table 1-6.

*NOTE The SYSTem:PRESet and *RST defaults are listed in the SCPI tables in Section 14.*

Table 1-6
Default setups commands

Commands	Description
:SYSTem:PRESet	Restore SYSTem:PRESet defaults.
*RST	Restore *RST defaults.
*SAV <NRf>	Save settings as user setup; <NRf> = 0, 1, 2, or 3.
*RCL <NRf>	Restore user saved setup; <NRf> = 0, 1, 2, or 3.
:SYSTem:POSetup <name>	Specify power-on setup; <name> = RST, PRESet, SAV0, SAV1, SAV2 or SAV3.

Programming example

```
*SAV 2                  ' Save present setup in memory location 2.
:SYST:POS SAV2          ' Specify SAV2 setup as the power-on setup.
*RST                    ' Return 2700 to RST defaults.
*RCL 2                  ' Return 2700 to setup stored in memory location 2.
```

Remote programming information

Remote programming information is integrated with front panel operation throughout this manual. Programming commands are listed in tables, and additional information that pertains exclusively to remote operation is provided after each table. The tables may reference you to other sections of this manual.

NOTE *Except for Sections 10 through 14, most programming tables in this manual are abridged. That is, they exclude most optional command words and query commands. Optional command words and query commands are summarized as follows.*

Optional command words — In order to be in conformance with the IEEE-488.2 standard, Model 2700 accepts optional command words. Any command word that is enclosed in brackets ([]) is optional and does not have to be included in the program message.

Query commands — Most command words have a query form. A query command is identified by the question mark (?) that follows the command word. A query command requests (queries) the programmed status of that command. When a query command is sent and Model 2700 is addressed to talk, the response message is sent to the computer.

NOTE *For complete details, see "Programming syntax" in Section 9.*

2
Basic Operation

- **Basic operation overview** — Summarizes the measurement capabilities of the Model 2700, and the switching capabilities of the Model 7700 switching module.
- **High energy circuit safety precautions** — Provides safety information when performing measurements in high energy circuits.
- **Performance considerations** — Covers some considerations that affect overall performance including warm-up, autozero and line synchronization.
- **Channel list parameter (<clist>)** — Summarizes the use of the <clist> parameter which is used throughout this manual to configure scan channels.
- **Model 7700 switching module** — Provides the detailed operating information for using the switching module.
- **Basic measurements** — Provides detailed information for making voltage, current, resistance, frequency, period, temperature, and continuity measurements.

Basic operation overview

NOTE *Accuracy specifications for all measurement functions and Keithley switching modules are provided in Appendix A.*

Measurement capabilities

The Model 2700 can make the following measurements:
DCV - DC voltage measurements from 0.1µV to 1000V.
ACV - AC voltage measurements from 0.1µV to 750V.
DCI - DC current measurements from 10nA to 3A.
ACI - AC current measurements from 1µA to 3A.
Ω2 - 2-wire resistance measurements from 100µΩ to 120MΩ.
Ω4 - 4-wire resistance measurements from 100µΩ to 120MΩ.
FREQ - Frequency measurements from 3Hz to 500kHz.
PERIOD - Period measurements from 2µs to 333µs.
TEMP - Temperature measurements from -200°C to 1820°C.
CONT - Continuity testing using the 1kΩ range.

Model 7700 switching module capabilities

NOTE *Detailed information on other Keithley switching modules are provided in Appendices B, C, and D.*

Channels 1 through 20 — The Model 7700 can multiplex one of 20 2-pole signals, or one of 10 4-pole signals into the input of the Model 2700.

Channels 21 and 22 — The Model 7700 can multiplex one of two 2-pole current signals into the input of the Model 2700.

For scanning, each channel of the switching module can have its own unique configuration.

CAUTION **To prevent damage to the Model 7700 switching module, do not exceed these maximum signal levels:**

Channels 1-20: 300VDC or RMS, 1A switched, 60W, 125VA
Channels 21, 22: 60VDC or 30V RMS, 3A switched, 60V, 125VA

High energy circuit safety precautions

To optimize safety when measuring voltage in high energy distribution circuits, read and use the directions in the following warning.

WARNING **Dangerous arcs of an explosive nature in a high energy circuit can cause severe personal injury or death. If the multimeter is connected to a high energy circuit when set to a current range, low resistance range, or any other low impedance range, the circuit is virtually shorted. Dangerous arcing can result even when the multimeter is set to a voltage range if the minimum voltage spacing is reduced in the external connections.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, the Model 2700 is Installation Category I and must not be connected to mains.

When making measurements in high energy circuits, use test leads that meet the following requirements:

- Test leads should be fully insulated.
- Only use test leads that can be connected to the circuit (e.g., alligator clips, spade lugs, etc.) for hands-off measurements.
- Do not use test leads that decrease voltage spacing. These diminish arc protection and create a hazardous condition.

Use the following sequence when testing power circuits:

1. De-energize the circuit using the regular installed connect-disconnect device, such as a circuit breaker, main switch, etc.
2. Attach the test leads to the circuit under test. Use appropriate safety rated test leads for this application. If over 42V, use double insulated test leads or an additional insulation barrier for the operator.
3. Set the multimeter to the proper function and range.
4. Energize the circuit using the installed connect-disconnect device and make measurements without disconnecting the multimeter.
5. De-energize the circuit using the installed connect-disconnect device.
6. Disconnect the test leads from the circuit under test.

WARNING **For the front panel inputs, the maximum common-mode voltage (voltage between INPUT LO and the chassis ground) is 500V peak. For a switching module, the maximum common mode voltage is 300V. Exceeding these values may cause a breakdown in insulation, creating a shock hazard.**

Performance considerations

Warm-up

After the Model 2700 is turned on, it must be allowed to warm up for at least two hours to allow the internal temperature to stabilize. If the instrument has been exposed to extreme temperatures, allow extra warm up time.

Autozero

To help maintain stability and accuracy over time and changes in temperature, the Model 2700 periodically measures internal voltages corresponding to offsets (zero) and amplifier gains. For thermocouple temperature measurements using the internal reference junction (i.e., Model 7700 switching module installed), the internal temperature is also measured. These measurements are used in the algorithm to calculate the reading of the input signal. This process is known as autozeroing.

When autozero is disabled, the offset, gain and internal temperature measurements are not performed. This increases the measurement speed. However, the zero, gain, and temperature reference points will eventually drift resulting in inaccurate readings of the input signal. It is recommended that autozero only be disabled for short periods of time.

When autozero is enabled after being off for a long period of time, the internal reference points will not be updated immediately. This will initially result in inaccurate measurements, especially if the ambient temperature has changed by several degrees.

NOTE *To force a rapid update of the internal reference points, set the integration rate to 0.01 PLC, and then back to the desired rate (i.e., 1.0 PLC). The NPLC commands to set the integration rate are covered in Section 3.*

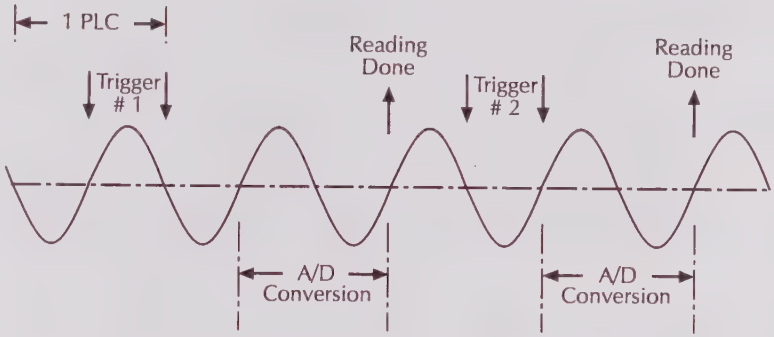
Remote programming can be used to enable or disable autozero (see Table 2-1). Autozero cannot be disabled from the front panel, however, it can be enabled by restoring factory default conditions.

LSYNC (line cycle synchronization)

Synchronizing A/D conversions with the frequency of the power line increases common mode and normal mode noise rejection. When line cycle synchronization is enabled, the measurement is initiated at the first positive-going zero crossing of the power line cycle after the trigger.

Figure 2-1 shows the measurement process that consists of two A/D conversions. If the trigger occurs during the positive cycle of the power line (Trigger #1), the A/D conversion starts with the positive-going zero crossing of the power line cycle. If the next trigger (Trigger #2) occurs during the negative cycle, then the measurement process also starts with the positive-going zero crossing.

Figure 2-1
Line cycle synchronization



Perform the following steps to enable or disable line cycle synchronization:

1. Press SHIFT and then LSYNC to display the present state of line synchronization (OFF or ON).
2. Use the up or down key to display "LINESYNC ON" or "LINESYNC OFF".
3. Press ENTER. The instrument returns to the normal display state.

NOTE *Line synchronization is not available for the AC functions (ACV, ACI, FREQ, or PERIOD), and for integration rates <1 PLC, regardless of the LSYNC setting.*

Remote programming - autozero and LSYNC

Autozero and LSYNC commands

The commands to control display resolution (digits) are listed in Table 2-1.

Table 2-1
Autozero and LSYNC commands

Commands	Description	Default
Autozero command:*		
:SYSTem:AZERo:STATe <b>	Enable or disable autozero; <b> = ON or OFF	ON
LSYNC command:		
:SYSTem:LYSNc[:STATe] <b>	Enable or disable LYSNC; <b> = ON or OFF	OFF

*After enabling autozero, you can update the internal reference points immediately by setting the integration rate to 0.01 PLC and then back to the desired setting (see NPLC commands in Section 3).

Channel list parameter (<clist>)

Channels of one or two switching modules installed in the Model 2700 can be scanned. Each scan channel can have its own unique setup. For example, a channel could be set to measure DCV on the 10V range, while another channel can be set to measure ACV on the 1V range.

From the front panel, scan channels are configured from the scan configuration menu as explained in Section 6. For remote programming, the <clist> parameter is used to configure scan channels.

Channel list parameter:

<clist> = (@SCH)

where: S = Mainframe slot number (1 or 2)
CH = Switching module channel number (must be 2 digits)

Examples: (@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

Throughout this manual, you will encounter commands that can use the <clist> parameter. The <clist> simply indicates that the associated command can be used to configure a scan channel. For example:

```
SENSe:FUNCtion 'VOLTage:AC'          ' Select ACV function.
SENSe:FUNCtion 'VOLTage:AC' (@101)   ' Configure scan channel 101 for ACV.
```

While in the normal measurement display state, the first command simply selects the ACV function. The second command configures channel 101 to measure ACV when it is scanned.

See Section 6 for detailed information on scanning.

Model 7700 switching module

NOTE *For information on other Keithley switching modules, see Appendices B and C.*

Overview

Maximum Signal Levels:

Channels 1 - 20:	300V DC or RMS, 1A switched, 60W, 125VA maximum
Channels 21 and 22:	60V DC or 30V RMS, 3A switched, 60W, 125VA maximum

NOTE *Complete specifications for the Model 7700 are provided in Appendix A.*

The Model 7700 multiplexing switching module has 20 2-pole channels that can be used for voltage, resistance, frequency, period, and temperature measurements. It also has two current-only channels.

The Model 7700 has six temperature transducers to monitor the cold junction temperature at the screw terminals. For temperature measurements, this internal reference junction allows thermocouples to be connected directly to the screw terminals of the module.

When the Model 2700 is on the DCV, ACV, Ω2, CONT, Ω4, FREQ, PERIOD, or TEMP function, channels 1 through 20 are available. When on a current function (DCI or ACI), channels 21 and 22 are the only available channels.

The Model 7700 can accommodate 4-wire measurements by using channel pairs. Primary channels 1 through 10 become paired to channels 11 through 20. For example, with the Ω4 function selected, channel 1 becomes paired to channel 11. For example, when you close channel 1, channel 11 will also close.

The 2-wire functions include DCV, ACV, DCI, ACI, Ω2, CONT, FREQ, PERIOD and TEMP (thermocouple and thermistor). The 4-wire functions/operations include Ω4, TEMP (4-wire RTD), RATIO, and CH AVG (ratio and channel average are covered in Section 4).

With a 4-wire function/operation selected, primary channels 1 through 10 automatically become paired to channels 11 through 20 as follows:

Channel 01 paired to Channel 11
Channel 02 paired to Channel 12
Channel 03 paired to Channel 13
Channel 04 paired to Channel 14
Channel 05 paired to Channel 15
Channel 06 paired to Channel 16
Channel 07 paired to Channel 17
Channel 08 paired to Channel 18
Channel 09 paired to Channel 19
Channel 10 paired to Channel 20

Schematic diagram

The schematic diagram of the Model 7700 is shown in Figure 2-2. Channels 1 through 20 are used for all measurements except amps. Channels 21 and 22 are used for amps only.

There are two backplane relays (channels 24 and 25) to connect the input channel(s) to the backplane of the Model 2700. With a 2-wire function (except amps) selected, channel 25 will close, and with a 4-wire function selected, both channels 24 and 25 will close.

There is a 2-pole/4-pole relay (channel 23) between channels 1-10 and channels 11-20. When a 2-wire function (i.e., DCV) is selected, channel 23 opens (2-pole position) to allow any of the 20 channels to be connected to the input backplane.

When a 4-wire function is selected, channel 23 closes (4-pole position) to isolate channels 1 through 10 from channels 11 through 20. When a primary channel (1 through 10) is closed, its paired channel (11 through 20) will also close to connect the sense channel to the sense backplane.

For the two current channels (21 and 22), signal HI and LO are routed directly to the backplane when the channel is closed.

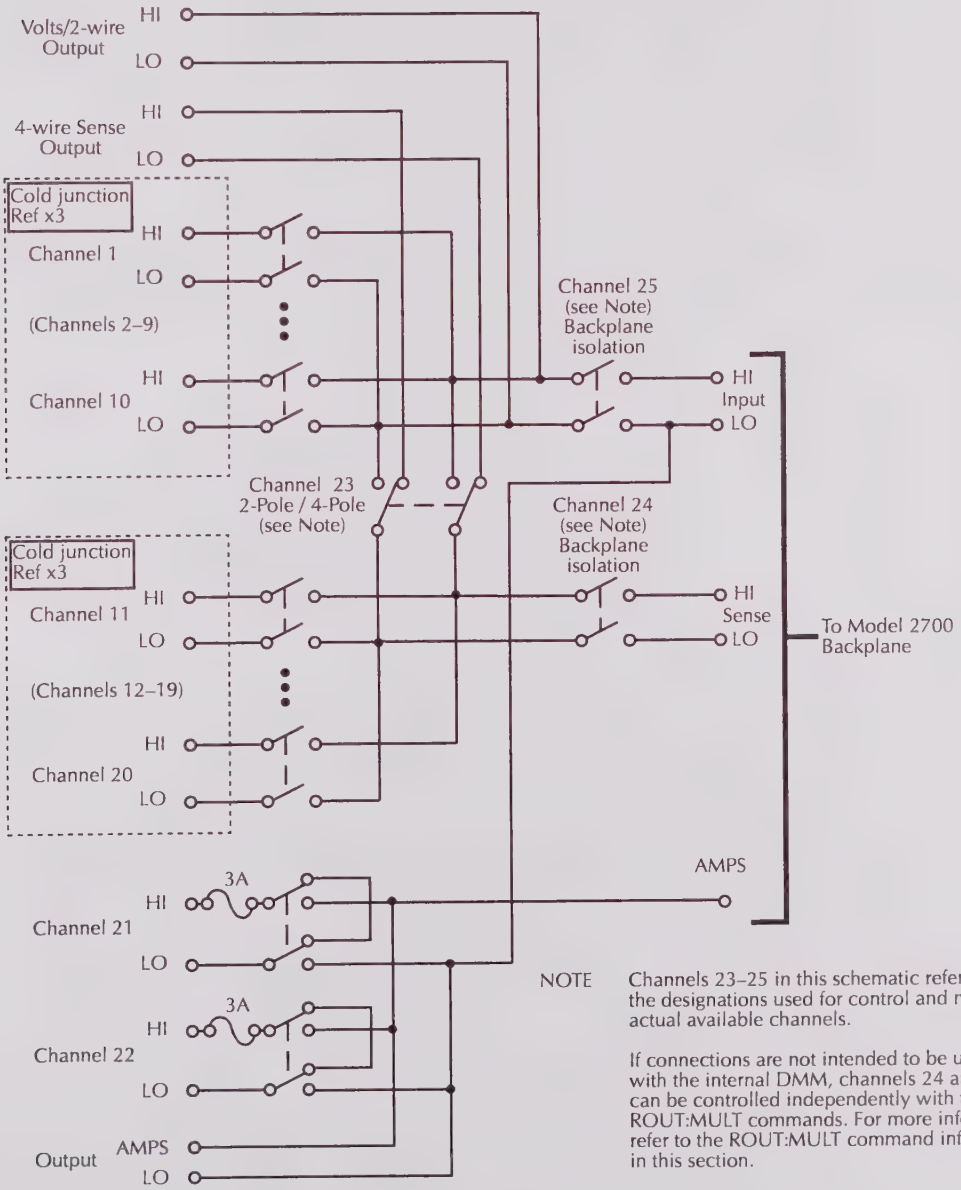
As shown in Figure 2-2, there are also screw terminals labeled "Volts/2-wire Output," "4-wire Output," and "Output." Volts/2-wire Output and 4-wire Output are connected to the inputs of channels 24 and 25 (isolation relays). If channels 1 through 20 are not intended to be connected to the internal DMM, channels 24 and 25 can be controlled independently using the ROUT:MULT commands. The Output (Amps and LO) terminals are connected directly to the DMM.

NOTES *For normal operation of the 22 measurement channels, only one channel (or channel pair) can be closed at the same time. When you close a channel (or channel pair), all other measurement channels will open.*

For normal operation, the user has no control of channels 23, 24, and 25. The open/close state of these channels are determined by the selected function.

For remote programming, the :ROUTe:MULTiple commands can be used to close multiple measurement channels, and control (open/close) channels 23, 24, and 25. For details, see "Mult-close/open operation."

Figure 2-2
Model 7700 simplified schematic



NOTE Channels 23–25 in this schematic refer to the designations used for control and not actual available channels.

If connections are not intended to be used with the internal DMM, channels 24 and 25 can be controlled independently with the ROUT:MULT commands. For more information, refer to the ROUT:MULT command information in this section.

Connections and installation

Channels 1 through 23 use latching relays to achieve better DC measurement performance (no thermal EMFs). If any of these relays are closed when the instrument is turned off, they will remain closed. Therefore, if you have a hazardous voltage connected to a closed channel, that voltage will also appear on the INPUT, SENSE, or AMPS/LO terminals of the Model 7700 switching module.

When the Model 2700 completes its power-up initialization, the closed channels will open after a few seconds.

WARNING **Never handle a switching module that is connected to an external source that is turned on. Turn off all power sources before (1) making or breaking connections to the module, and (2) installing (or removing) the module into (or out of) the Model 2700.**

The relays for the backplane (channels 24 and 25) are non-latching. They will open when the Model 2700 is turned off.

WARNINGS

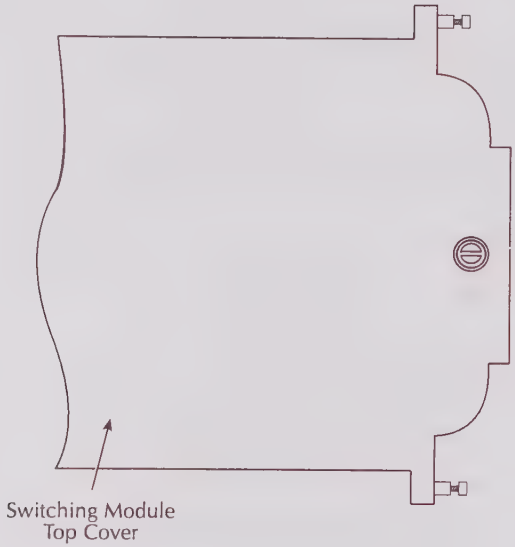
1. **Operators should not open top cover of switching module.**
2. **Make sure the cover is installed for safety. Do not handle switching module without the cover installed.**
3. **Modular wiring/connections are for qualified service personnel only. Refer to the appendices for more information.**

Top cover removal

To gain access to the screw terminals of the Model 7700 switching module, you will have to remove the top cover. As shown in Figure 2-3, there is a spring-loaded release screw. Using a thin-bladed screwdriver, turn the screw to the left until it releases. Carefully remove the top cover from the switching module.

When putting the top cover back on, make sure the tabs on the other end of the top cover engage into the slots of the switching module case. With the top cover properly positioned, press in the screw until it locks into place.

Figure 2-3
Model 7700
top cover



Module installation

Perform the following steps to install the Model 7700 switching module into the Model 2700 mainframe:

1. Turn the Model 2700 off and disconnect the power line cord and any other cable connected to the rear panel.
2. Position the Model 2700 so you are facing the rear panel.
3. With the top cover of the switching module facing up, slide the module into an empty slot. For the last ¼ inch or so, press in firmly to mate the module connector to the mainframe connector.
4. On each side of the module, there is a mounting screw. Tighten these two screws to secure the module to the mainframe. Do not overtighten.
5. Re-connect the power line cable, and any other cables to the rear panel.
6. When you turn on the Model 2700, the message "7700" will be momentarily displayed for the appropriate slot.

Basic operation

Channel assignments

The Model 2700 has two slots for switching modules. The top slot is Slot 1, and the bottom slot is Slot 2. To control the appropriate switching module, the slot number must precede the switching module channel number when you specify a channel. Examples:

101 = Slot 1, Channel 1
110 = Slot 1, Channel 10
206 = Slot 2, Channel 6
222 = Slot 2, Channel 22

Open/close channels

For basic operation, when you close a channel, the previously closed channel(s) will open before the specified channel closes. Keep in mind that for a 4-wire measurement the paired channel will also close.

With a Model 7700 installed in both slots 1 and 2, the available channels are 101 to 122 and 201 to 222. However, keep in mind that with a 4-wire function selected, only channels 101 to 110, and 201 to 210 can be controlled.

When you close a channel, the channel number will be displayed and the CHAN annunciator turns on. For a 4-wire measurement, the paired channel that is also closed is not displayed.

From the front panel, there are two ways to close a channel (or channel pair). You can use the CLOSE key or you can use the ◀ and ▶ keys.

CLOSE key

When using the CLOSE key, you specify the channel you want to close as follows:

1. Press CLOSE to display "CLOSE CH: XXX".
2. Using ◀, ▶, ▲, and ▼ key in the three-digit channel you want to close.
3. Press ENTER. The channel closes and the CHAN annunciator turns on.

NOTE *If you try to close a channel that is unavailable (i.e., 225) or not controllable (i.e., channel 111 with Ω4 selected), an error message ("TOO LARGE" or "INVALID CHAN") will be displayed briefly. The "CLOSE CH: XXX" display will then default to a channel that can be closed.*

4. When finished, press OPEN to open all channels.

OPEN key

Press the OPEN key to open all input signal channels. For the Model 7700, channels 1 through 22 will open.

NOTE *Pressing OPEN disables the ratio and channel average calculation (see Section 4 for details on ratio and channel average).*

◀ and ▶ keys

While in the normal measurement state, you can use the ◀ and ▶ keys to close channels. In general, pressing ▶ closes the next available channel, while ◀ closes the previous channel.

With no channels closed, pressing ▶ will close the first available channel. If you instead press ◀, the last available channel will close. For example, assume the DCV function is selected and there is a Model 7700 module installed in both slots 1 and 2. The first available channel is 101 and the last available channel is 220.

Scanning channels

With two Model 7700 switching modules installed, the Model 2700 can scan up to 40 channels. Each available channel can have its own unique setup when it is scanned. For example, channel 101 can be configured to measure DCV on the 10V range when it is scanned, while channel 102 can be configured to measure ACV on the 1V range when it is scanned.

Scanning is covered in Section 6.

Auto channel configuration

For normal open/close operation, the present instrument setup (i.e., function, range, digits, etc.) does not change when you close and open channels. However, if you enable auto channel configuration, the instrument will assume the scan channel configuration when the channel is closed. For example, assume scan channel 101 is set for Ω2 and scan channel 102 is set for ACV. When channel 101 is closed, the instrument will measure Ω2, and when channel 102 is closed, it will measure ACV.

When a scan channel is disabled (not in scan list), it cannot be closed with auto channel configuration enabled.

From the front panel, scan channels are configured from the scan configuration menu as explained in Section 6. For remote programming, the <clist> parameter is used to configure scan channels (see "Channel list parameter").

Perform the following steps to enable or disable auto channel configuration:

1. Press SHIFT and then SETUP.
2. Use the ▼ key to display the present state of auto channel configuration (CH AUTCFG); N (no) or Y (yes).
3. To change the setting, press the ▶ key to place the cursor on the present setting (N or Y), and press the ▲ or ▼ key.
4. With the desired setting displayed, press ENTER.

Mult-close/open operation

The :ROUTe;MULTiple commands allow independent control (open/close) of all 22 input channels, the two backplane relays, and the 2-pole/4-pole relay. As shown in Figure 2-2, those three relays are assigned the following channel numbers:

Channel 23: 2-pole/4-pole relay
Channel 24: Sense backplane isolation relay
Channel 25: Input backplane isolation relay

Being able to control all channels of the Model 7700 provides you with added flexibility in how you use the module. For example, assume you want to route a signal into channel 1 and out channel 20. You would do this by closing channels 1, 20, and 23. If you open channels 24 and 25, you will isolate the input signal from the backplane of the Model 2700.

An application is to use channels 1 through 10 to measure a DUT, and use channels 11 through 20 to switch as follows:

- Close channel 23 to isolate the measurement channels from the bias supply channels.
- Open channel 24 to isolate the bias supply from the backplane of the Model 2700.
- Close channel 25 to measure an input channel (1 through 10).
- Connect the bias supply to the SENSE HI and LO terminals of the Model 7700.

This setup will allow you to bias and measure up to 10 DUT. Each DUT is connected to a measurement channel and a bias supply channel. Typically, you would connect channels 1 and 11 to a DUT, channels 2 and 12 to another DUT, channels 3 and 13 to another DUT, and so on. When channels 1 and 11 are closed, the DUT will be biased and measured as shown in Figure 2-4. To measure the next DUT, you must first open channels 1 and 11 and then close the next pair of channels.

WARNING **When using mult-close operation, you must be very careful when switching hazardous voltages. If you inadvertently close the wrong channel(s), you could create a shock hazard and/or cause damage to the equipment.**

Closed channels (1 through 23) remain closed when the Model 2700 is turned off. Never handle a switching module that is connected to an external source that is turned on. Turn off all power sources before (1) making or breaking connections to the module, and (2) installing (or removing) the module into (or out of) the Model 2700.

NOTE *The mult-close/open commands are listed in Table 2-2 (see "Remote programming - close/open channels").*

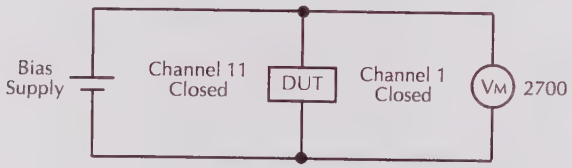


Figure 2-4
Mult-close application

Remote programming - close/open channels

Close/open commands

The commands to close and open channels are listed in Table 2-2.

Table 2-2
Close and open commands

Commands	Description	Ref
:ROUTe:CLOSe <clist>	Specify one channel to close.	A
:ROUTe:CLOSe:STATe? <clist>	Query closed channels in specified list (1 = closed).	B
:ROUTe:CLOSe?	Returns a <clist> of closed measurement channels.	C
:ROUTe:OPEN:ALL	Open all input channels, and disable ratio and channel average.	
:ROUTe:CLOSe:ACONfigure <b>	Enable or disable auto channel configuration.	
:ROUTe:MULTiple:CLOSe <clist>	Close channels specified in list. Unlisted channels not affected.	D
:ROUTe:MULTiple:OPEN <clist>	Open channels specified in list. Unlisted channels not affected.	E
:ROUTe:MULTiple:CLOSe?	Returns a <clist> of all closed channels.	F
:ROUTe:MULTiple:CLOSe:STATe? <clist>	Query closed channels in specified list (1 = closed).	G
Channel list parameter: <clist> = (@SCH) where: S = Mainframe slot number (1 or 2) CH = Switching module channel number (must be 2 digits) Examples: (@101) = Slot 1, Channel 1 (@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3 (@101:110) = Slot 1, Channels 1 through 10		

Reference:

A. :ROUTe:CLOSe <clist>

This command functions the same as the front panel CLOSE key. When this command is sent, any closed measurement channel (or channel pair) is first opened. Then the specified measurement channel (or channel pair) is closed.

Relays for sense selection and connection to the backplane close automatically for the selected function. For the Model 7700, you cannot use this command to close channels 23, 24, or 25.

NOTE *If you try to close an invalid channel (i.e., channel 21 for DCV), a settings conflict error (-221) will occur.*

B. :ROUTe:CLOSe:STATe? <clist>

This query returns a "0" (open) or "1" (closed) for every channel specified the <clist>. For example, assume <clist> = (@101, 104, 107, 102). The response message "0, 0, 1, 0" indicates that channel 107 is closed.

Model 7700 switching module — Channels 1 through 22 are valid channels for the <clist> parameter. The state of channels 23, 24, and 25 cannot be checked with this query command.

C. :ROUTe:CLOSe?

This query command returns a <clist> of closed channels, including paired channels for 4-wire functions.

Model 7700 switching module — This query command will not return channels 23, 24, and 25.

D. :ROUTe:MULTiple:CLOSe <clist>

With this command, you can close one or more switching module channels, including the relays that select sense and connect channels to the backplane. You can also close more than one channel at a time.

When you send this command to close the channels specified in the <clist>, only those channels will close. Channels not specified are not affected, and channel pairing is disabled.

NOTE *Channels closed by this command are not displayed.*

E. :ROUTe:MULTiple:OPEN <clist>

With this command, you can open one or more switching module channels, including the relays that select sense and connect channels to the backplane.

When you send this command to open the channels specified in the <clist>, only those channels will open. Channels not specified are not affected.

F. :ROUTe:MULTiple:CLOSe?

This query command is similar to :ROUTe:CLOSe?, except it will also return channels that control sensing and connection to the backplane. For the Model 7700, those are channels 23, 24, and 25.

G. :ROUTe:MULTiple:CLOSe:STATe? <clist>

This query command is similar to :ROUTe:CLOSe:STATe, except that you can specify the relay channels to control sense selection and connection to the backplane. For the Model 7700, those are channels 23, 24, and 25.

Programming example

The following commands demonstrate how to close channels:

```
*RST                                ' Restore *RST defaults (DCV).
ROUT:CLOS (@101)                    ' Close channel 1 (channel 25 closes
                                    ' automatically).
ROUT:CLOS (@111)                    ' Close channel 11 (channels 23 and 25
                                    ' close automatically).
ROUT:MULT:CLOS (@101, @111)         ' Close only channels 1 and 11.
```

Basic measurements

Voltage measurements (DCV and ACV)

The Model 2700 can make DCV measurements from 0.1µV to 1000V and ACV measurements from 0.1µV to 750V RMS, 1000V peak.

DCV input resistance:	100V and 1000V ranges: 10MΩ 100mV, 1V, and 10V ranges: >10GΩ || <400pF or 10MΩ
ACV input impedance:	1MΩ || <100pF

DCV input divider

Normally, the input resistance for the 100mVDC, 1VDC, and 10VDC ranges is >10GΩ, while the input resistance of the 100VDC and 1000VDC ranges is 10MΩ. However, the input resistance for the three lower DCV ranges can also be set to 10MΩ by enabling the input divider.

With the input resistance lowered, a more stable 0V reading is achieved with an open input. Also, some external devices (such as a high voltage probe) must be terminated to a 10MΩ load.

The input divider cannot be enabled from the front panel. For remote programming, the following command controls the input divider:

```
[:SENSe[1]]:VOLT[DC]:IDIVider <b>    ' Enable or disable the DCV input divider.
```

Connections

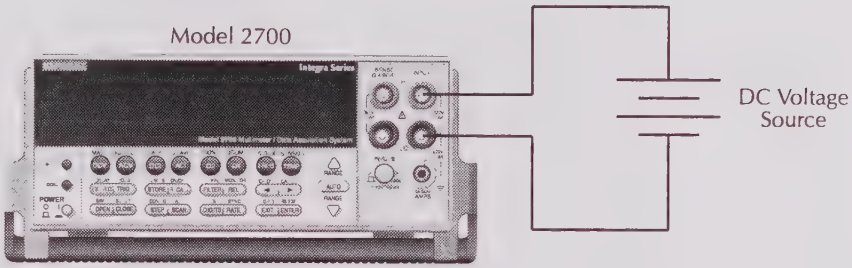
WARNING **Even though the Model 2700 can measure up to 1000V peak, the maximum input to a switching module is 300VDC or RMS. Exceeding 300V to a switching module may cause damage and create a safety hazard.**

NOTE *When using the front panel inputs, the INPUTS switch must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

Front panel input

When using the front panel input terminals, connect the test leads to the INPUT HI and LO terminals as shown in Figure 2-5.

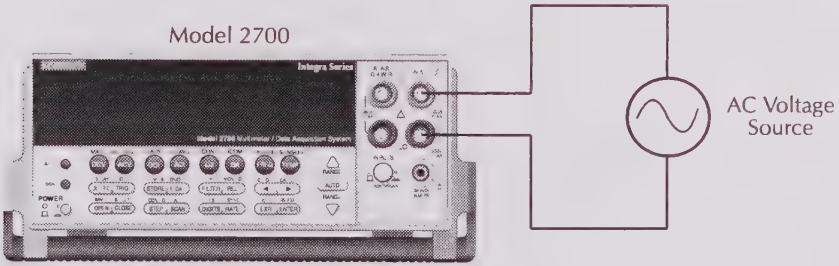
Figure 2-5
DCV and ACV connections using front panel inputs



Input Resistance = 10MΩ on 1000V and 100V ranges;
>10GΩ on 10V, 1V, and 100mV ranges.

Caution: Maximum Input = 1000V peak

A) DCV Connections



Input Impedance = 1MΩ || <100pF

Caution: Maximum Input = 750V RMS, 1000V peak, 8×10^7 V • Hz

B) ACV Connections

Model 7700 switching module

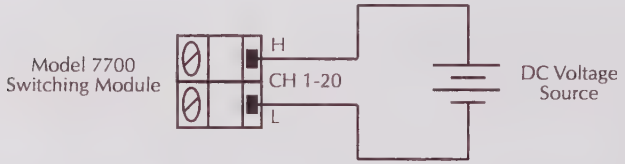
Connections for the Model 7700 switching module are shown in Figure 2-6. For basic DCV and ACV measurements (Figure 2-6A and B), channels 1 through 20 can be used.

Ratio and channel average calculations - Ratio calculates the reading ratio of two channels, while channel average calculates the reading average of two channels. For these calculations, paired switching channels are used. Primary channels 1 through 10 are paired to channels 11 through 20 (channel 1 paired to channel 11, channel 2 paired to channel 12, and so on). As shown in Figure 2-6C, one DC voltage source is connected to a primary channel (i.e., 104), and the other source is connected to its paired channel (i.e., 114).

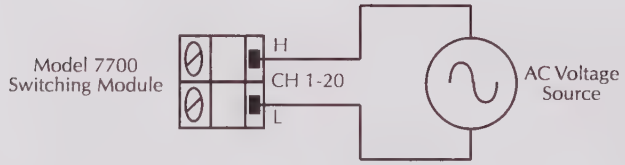
NOTE *The ratio and channel average calculations are covered in Section 4.*

Figure 2-6
DCV and ACV connections using Model 7700 switching module

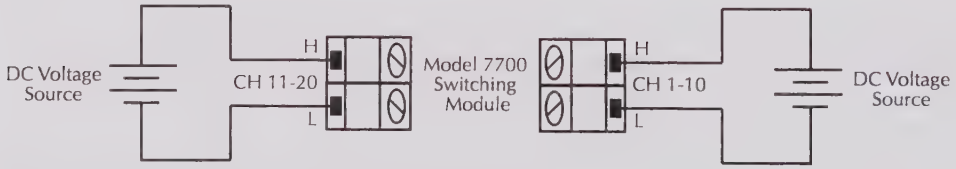
Caution: Maximum input: 300VDC or RMS, 1A switched, 60W, 125VA maximum



A) DCV connections



B) ACV connections



Note: The low connections for channels 1 through 10 do not need to be referenced to the low connections for channels 11 through 20.

C) Ratio and channel average connections (DCV)

Volts measurement procedure

NOTE *Make sure the INPUTS switch is in the correct position. To use front panel inputs, it must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

1. If a switching channel is presently closed (displayed), press OPEN to open it.
2. Select the volts measurement function by pressing DCV or ACV.
3. Use the RANGE ▲ and ▼ keys to select a measurement range consistent with the expected voltage, or press AUTO to select autoranging (AUTO annunciator turns on). Details on range are provided in Section 3.
4. Apply the voltage(s) to be measured.

CAUTION **Do not apply more than maximum input levels indicated in Figure 2-5 and Figure 2-6 or instrument damage may occur. The voltage limit is subject to the 8×10^7V•Hz product.**

Model 7700 switching module - The maximum allowable voltage is 300V DC or RMS. Exceeding these limits may cause damage to the switching module.

WARNING **If both the front panel terminals and the switching module terminals are connected at the same time, the test leads must be rated to the highest voltage that is connected. For example, if 1000V is connected to the front panel input, the test lead insulation for the switching module must also be rated for 1000V.**

5. If using a switching module, perform the following steps to close the desired channel:
   a. Press the CLOSE key.
   b. Use ◀, ▶, ▲, and ▼ to key in the channel number and press ENTER. The previously closed channel (if there is one) will open, and the specified channel will close.

NOTE *While in the normal measurement state, you can use the ◀ and ▶ keys to close channels. In general, each key press will open the presently closed channel, and then close the next higher or lower channel.*

6. Observe the displayed reading. If the "OVERFLOW" message is displayed, select a higher range until a normal reading is displayed (or press AUTO for autoranging). For manual ranging, use the lowest possible range for the best resolution.
7. To measure other switching channels, repeat steps 5 and 6.
8. When finished, press OPEN if there is a channel closed.

Crest factor

AC voltage (and current) accuracies are affected by the crest factor of the waveform, the ratio of the peak value to the RMS value. Table 2-3 lists the fundamental frequencies at which the corresponding crest factor must be taken into account for accuracy calculations.

Table 2-3
Crest factor limitations

Crest factor	Fundamental frequency
2	50kHz
3	3kHz
4-5	1kHz

Low level considerations

For sensitive measurements, external considerations beyond the Model 2700 affect the accuracy. Effects not noticeable when working with higher voltages are significant in microvolt signals. The Model 2700 reads only the signal received at its input; therefore, it is important that this signal be properly transmitted from the source. The following paragraphs indicate factors that affect accuracy, including stray signal pick-up and thermal offsets.

Shielding

AC voltages that are extremely large compared with the DC signal to be measured may produce an erroneous output. Therefore, to minimize AC interference, the circuit should be shielded with the shield connected to the Model 2700 input low (particularly for low level sources). Improper shielding can cause the Model 2700 to behave in one or more of the following ways:

- Unexpected offset voltages.
- Inconsistent readings between ranges.
- Sudden shifts in reading.

To minimize pick-up, keep the voltage source and the Model 2700 away from strong AC magnetic sources. The voltage induced due to magnetic flux is proportional to the area of the loop formed by the input leads. Therefore, minimize the loop area of the input leads and connect each signal at only one point.

Thermal EMFs

Thermal EMFs (thermoelectric potentials) are generated by thermal differences between the junctions of dissimilar metals. These can be large compared to the signal that the Model 2700 can measure. Thermal EMFs can cause the following conditions:

- Instability or zero offset is much higher than expected.
- The reading is sensitive to (and responds to) temperature changes. This effect can be demonstrated by touching the circuit, by placing a heat source near the circuit, or by a regular pattern of instability (corresponding to changes in sunlight or the activation of heating and air conditioning systems).

To minimize the drift caused by thermal EMFs, use copper leads to connect the circuit to the Model 2700.

For front panel inputs, a banana plug generates a few microvolts. A clean copper conductor such as #10 bus wire is ideal for this application. For switching modules, use #20 AWG copper wire to make connections. The leads to the Model 2700 may be shielded or unshielded, as necessary. Refer to "Shielding."

Widely varying temperatures within the circuit can also create thermal EMFs. Therefore, maintain constant temperatures to minimize these thermal EMFs. A shielded enclosure around the circuit under test also helps by minimizing air currents.

The REL control can be used to null out constant offset voltages.

AC voltage offset

The Model 2700, at 5½ digits resolution, will typically display 100 counts of offset on AC volts with the input shorted. This offset is caused by the offset of the TRMS converter. This offset will not affect reading accuracy and should not be zeroed out using the REL feature. The following equation expresses how this offset (V_{OFFSET}) is added to the signal input (V_{IN}):

$$\text{Displayed reading} = \sqrt{(V_{IN})^2 + (V_{OFFSET})^2}$$

Example: Range = 1VAC
Offset = 100 counts (1.0mV)
Input = 100mV RMS

$$\text{Displayed reading} = \sqrt{(100\text{mV})^2 + (1.0\text{mV})^2}$$

$$= \sqrt{0.01\text{V} + (1 \times 10^{-6}\text{V})}$$

$$= 0.100005\text{ V}$$

The offset is seen as the last digit, which is not displayed. Therefore, the offset is negligible. If REL were used to zero the display, the 100 counts of offset would be subtracted from V_{IN}, resulting in an error of 100 counts in the displayed reading.

Current measurements (DCI and ACI)

The Model 2700 can make DCI measurements from 10nA to 3A and ACI measurements from 1μA to 3A RMS.

NOTE *See the previous discussion about crest factor in "Voltage measurements" in this section.*

Connections

NOTE *When using the front panel inputs, the INPUTS switch must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

WARNING **To prevent electric shock, never make or break connections while power is present in the test circuit.**

Front panel inputs

When using the front panel input terminals, connect the test leads to the AMPS and INPUT LO terminals as shown in Figure 2-7.

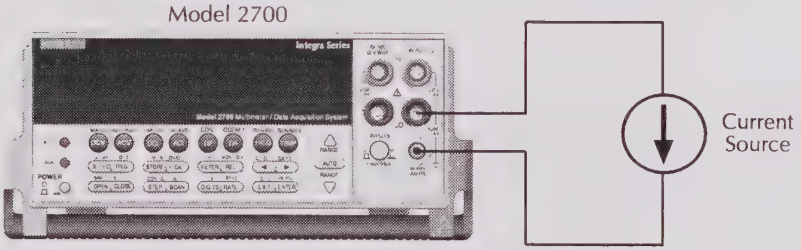


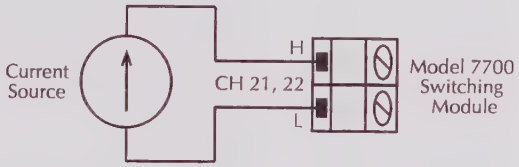
Figure 2-7
DCI and ACI connections using front panel inputs

Caution: Maximum Input = 3A DC or RMS

Model 7700 switching module

Connections for the Model 7700 switching module are shown in Figure 2-8. Note that only channels 21 and 22 can be used for current measurements.

Figure 2-8
DCI and ACI connections using Model 7700 switching module



Caution: Maximum input: 60VDC or 30V RMS, 3A switched, 60W, 125VA maximum

Amps measurement procedure

NOTE *Make sure the INPUTs switch is in the correct position. To use front panel inputs, it has to be in the "F" (out) position. For switching modules, it has to be in the "R" (in) position.*

1. If a switching channel is presently closed (displayed), press OPEN to open it.
2. Select the amps measurement function by pressing DCI or ACI.
3. Use the RANGE ▲ and ▼ keys to select a measurement range consistent with the expected current, or press AUTO to select autoranging (AUTO annunciator turns on). Details on range are provided in Section 3.
4. Apply the current(s) to be measured.

CAUTION **Do not apply more than 3A to the input or the AMPS fuse will blow.**

Model 7700 switching module - When performing current measurements, the maximum allowable voltage is 60VDC or 30V RMS. Exceeding these limits could cause damage to the switching module.

5. If using a switching module, use the ◀ and ▶ keys to close the desired amps channel (for the Model 7700, 21 or 22). All other channels will be open.
6. Observe the displayed reading. If the "OVERFLOW" message is displayed, select a higher range until a normal reading is displayed (or press AUTO for autoranging). For manual ranging, use the lowest possible range for the best resolution.
7. To measure another amps channel, repeat steps 5 and 6.
8. When finished, press OPEN if there is a channel closed.

NOTE *When you have an amps-only channel closed, you cannot select a non-amps function. For example, if channel 21 of the Model 7700 is closed, you cannot select the DCV function ("INVALID FUCN" displayed).*

AMPS fuse replacement (front panel AMPS input)

WARNING **Make sure the instrument is disconnected from the power line and other equipment before replacing the AMPS fuse.**

1. Turn off the power and disconnect the power line and test leads.
2. From the front panel, gently push in the AMPS jack with your thumb and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure on the jack and its internal spring will push the jack out of the socket.
3. Remove the fuse and replace it with the same type (3A, 250V, fast-blow, 5 × 20mm). The Keithley part number is FU-99-1.

CAUTION **Do not use a fuse with a higher current rating than specified or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.**

4. Install the new fuse by reversing the procedure above.

Resistance measurements (Ω2 and Ω4)

The Model 2700 can make 2-wire and 4-wire resistance measurements from 100μΩ to 120MΩ.

Connections

NOTE *When using the front panel inputs, the INPUTS switch must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

Front panel inputs

Connections for resistance measurements are shown in Figure 2-9. For 2-wire resistance measurements (Ω2), connect the test leads to INPUT HI and LO as shown in Figure 2-9A. For 4-wire resistance (Ω4), connect the test leads to INPUT HI and LO, and SENSE Ω4 HI and LO as shown in Figure 2-9B.

NOTE *See the service manual to replace the amps fuses for the Models 7700 and 7702 switching modules.*

Model 7700 switching module

Connections for the switching module are shown in Figure 2-10. As shown in Figure 2-10A, each of the 20 channels can be used to perform Ω2 measurements. For Ω4 measurements, a channel pair is used for each 4-wire measurement as shown in Figure 2-10B.

For Ω4 connections, channels 1 through 10 (which are used as the INPUT terminals) are paired to channels 11 through 20 (which are used as the SENSE terminals). Channel 1 is paired to channel 11, channel 2 is paired to channel 12, and so on.

Shielding

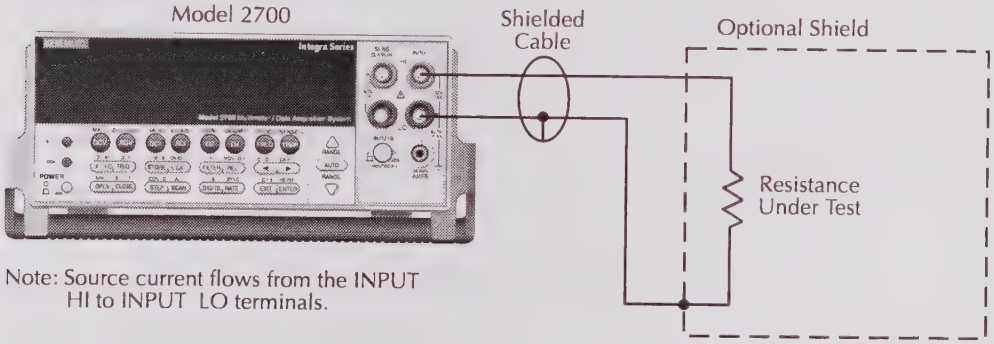
To achieve a stable reading, it helps to shield resistances greater than 100kΩ. As shown in Figure 2-9 and Figure 2-10, place the resistance in a shielded enclosure and connect the shield to the input low terminal of the instrument electrically.

Cable leakage

For high resistance measurements in a high humidity environment, use Teflon™ insulated cables to minimize errors due to cable leakage.

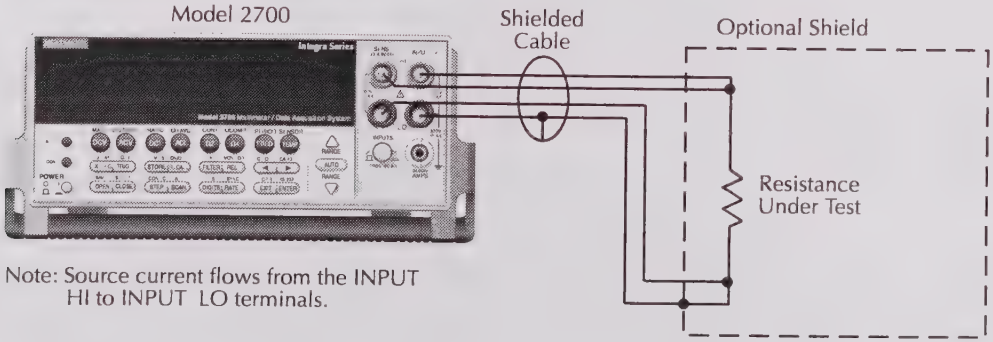
Figure 2-9
Ω2 and Ω4 connections for front panel inputs

A) Ω2 Connections



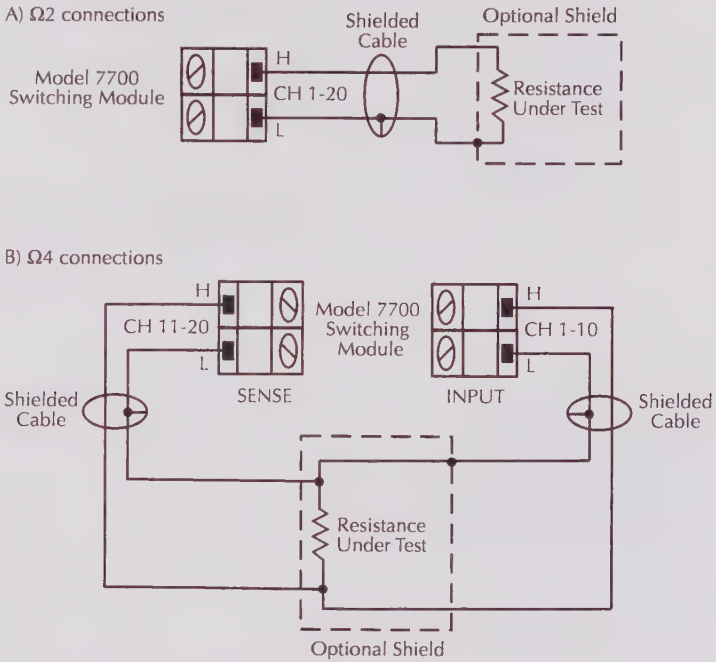
Note: Source current flows from the INPUT HI to INPUT LO terminals.

B) Ω4 Connections



Note: Source current flows from the INPUT HI to INPUT LO terminals.

Figure 2-10
Ω2 and Ω4 connections for Model 7700 switching module



Note: Source current flows from input high (H) to input low (L).

Ohms measurement procedure

NOTE *Make sure the INPUTS switch is in the correct position. To use front panel inputs, it must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

1. If a switching channel is presently closed (displayed), press OPEN to open it.
2. Select the ohms measurement function by pressing Ω2 or Ω4.
3. Use the RANGE ▲ and ▼ keys to select a measurement range consistent with the expected resistance, or press AUTO to select autoranging (AUTO annunciator turns on). Details on range are provided in Section 3.
4. Apply the resistance(s) to be measured.

CAUTION **Front panel inputs - Do not apply more than 1000V peak between INPUT HI and LO, or instrument damage may occur**

Model 7700 switching module - Do not apply more than 300V DC or RMS between input high (H) or input low (L), or switching module damage may occur.

5. If using a switching module, perform the following steps to close the desired channel. Keep in mind, that for Ω4 measurements, you will close the primary (INPUT) channel (1 through 10). The channel that it is paired to will close automatically.
   a. Press the CLOSE key.
   b. Use ◀, ▶, ▲, and ▼ to key in the channel number and press ENTER. The previously closed channel(s) (if any) will open, and the specified channel (or channel pair) will close.

NOTE *While in the normal measurement state, you can use the ◀ and ▶ keys to close channels. In general, each key press will open the presently closed channel, and then close the next higher or lower channel.*

6. Observe the displayed reading. If the "OVERFLOW" message is displayed, select a higher range until a normal reading is displayed (or press AUTO for autoranging). For manual ranging, use the lowest possible range for the best resolution.
7. To measure other switching channels, repeat steps 5 and 6.
8. When finished, press OPEN if there is a channel closed.

Offset compensated ohms

The presence of thermal EMFs (V_{EMF}) can adversely affect low-resistance measurement accuracy. To overcome these unwanted offset voltages, you can use offset compensated ohms. Offset compensated ohms measurements can be performed on the 100Ω, 1kΩ, and 10kΩ ranges for the Ω4 function. It cannot be done on the Ω2 function.

For a normal resistance measurement, the Model 2700 sources a current (I) and measures the voltage (V). The resistance (R) is then calculated (R=V/I) and the reading is displayed.

For offset compensated ohms, two measurements are performed: one normal resistance measurement, and one using the lowest current source setting.

The offset compensated ohms reading is then calculated as follows:

Offset compensated ohms reading = DV/DI

where: DV = V2 - V1
DI = I2 - I1

V1 is the voltage measurement with the current source at its normal level.
V2 is the voltage measurement using the lowest current source setting.

The above 2-point measurement process and reading calculation eliminates the resistance contributed by the presence of V_{EMF}.

Enabling/disabling offset compensated ohms

Offset compensated ohms is enabled by pressing SHIFT and then OCOMP. When enabled, the OCOMP annunciator is on. Offset compensated ohms is disabled by again pressing SHIFT and then OCOMP.

Performing offset compensated ohms measurements

Offset compensated ohms can only be performed on the Ω4 function using the 100Ω, 1kΩ, or 10kΩ range. Make sure you use 4-wire connections to the DUT (see "Connections").

NOTE *Make sure the INPUTS switch is in the correct position. To use front panel inputs, it must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

1. If a switching channel is presently closed (displayed), press OPEN to open it.
2. Select the 4-wire ohms measurement function by pressing Ω4, and enable offset compensated ohms by pressing SHIFT and then OCOMP (OCOMP annunciator turns on).
3. Use the RANGE up and down keys to select the 100Ω, 1kΩ, or 10kΩ range, or press AUTO to enable auto range. If using auto range, offset compensated ohms measurements will not be performed if the instrument goes to the 100kΩ or higher range.
4. Perform the rest of the basic "Ohms measurement procedure" starting at step 4.

NOTE *The OCOMP annunciator will flash when the instrument is on an invalid range (100kΩ through 100MΩ ranges) for offset compensated ohms. Normal ohms measurements will instead be performed.*

For buffer recall, there is no way to distinguish between a normal ohms reading and an offset compensated ohms reading. The OCOMP annunciator (off, on, or flashing) has no significance for recalled resistance readings that are displayed. Buffer operation is covered in Section 5.

Temperature measurements

The Model 2700 can measure temperature using thermocouples, thermisters, and 4-wire RTDs. When deciding which temperature sensor to use, keep in mind that the thermocouple is the most versatile, the thermistor is the most sensitive, and the 4-wire RTD is the most stable.

Thermocouples

For thermocouples, temperature measurement range depends on which type of thermocouple is being used. Thermocouples that are supported include types J, K, N, T, E, R, S, and B.

Type	Range	Resolution
J	-200°C to 760°C	0.001°C
K	-200°C to 1372°C	0.001°C
N	-200°C to 1300°C	0.001°C
T	-200°C to 400°C	0.001°C
E	-200°C to 1000°C	0.001°C
R	0°C to 1768°C	0.1°C
S	0°C to 1786°C	0.1°C
B	+350°C to 1820°C	0.1°C

When two wires made up of dissimilar metals are joined together, a voltage is generated. The generated voltage is a function of temperature. As temperature changes, the voltage changes. The thermocouple voltage equates to a temperature reading. This is the basic operation principle of the thermocouple.

When you connect a thermocouple directly to the input of the Model 2700, at least one of those connections will be a junction made up of two dissimilar metals. Hence, another voltage is introduced and is algebraically added to the thermocouple voltage. The result will be an erroneous temperature measurement.

To cancel the affects of the unwanted thermal voltage, the thermocouple circuit requires a reference junction that is at a known temperature.

Reference junctions

A reference junction is the cold junction in a thermocouple circuit which is held at a stable, known temperature. It is at the cold junction where dissimilar wire connections must be made. As long as the temperature of the cold junction is known, the Model 2700 can factor in the reference temperature to calculate the temperature reading at the thermocouple.

The standard reference temperature is the ice point (0°C). The ice point can be precisely controlled, and the National Bureau of Standards uses it as the fundamental reference for its voltage-to-temperature conversion tables. However, other known temperatures can be used.

There are two ways for the Model 2700 to acquire the cold junction temperature. It can measure the cold junction using a thermister or 4-wire RTD, or the known temperature value can be entered by the user.

Simulated reference junction - An example of a simulated reference junction is an ice bath (see Figure 2-11A and B). The copper wire to thermocouple wire connections are immersed (but electrically isolated) in the ice bath, and the user enters the 0°C simulated reference temperature into the Model 2700. The simulated reference temperature for the Model 2700 can be set from 0 to 65°C.

The Model 2700 measures the input voltage and factors in the simulated reference temperature to calculate the temperature reading at the thermocouple.

NOTE *The most accurate temperature measurements are achieved by using a simulated reference junction using an ice point reference.*

Internal reference junction - "Internal" implies that a temperature transducer(s) used to measure the cold junction is built into the instrument. For the Model 7700 switching module, the cold junction is the screw terminals, with voltage temperature sensors strategically placed to measure the temperature of the cold junction.

The Model 2700 measures the temperature of the cold junction (screw terminals), measures the input voltage, and then calculates the temperature reading at the thermocouple.

External reference junction - For switching modules that do not have built-in sensors to measure temperature, each module can use a thermistor or 4-wire RTD to acquire the reference temperature. Connect a thermistor to channel 1 or connect a 4-wire RTD to channel 1 and its paired channel.

Position the temperature transducer near the terminals for the channel(s) being used to measure temperature. Be sure to insulate the transducer leads to keep them from making contact with other conductors.

When you close channel 1 to measure the cold junction temperature, that temperature reading will be used to calculate the temperature when you close a thermocouple channel.

Open thermocouple detection

Long lengths of thermocouple wire can have a large amount of capacitance that is seen at the input of the DMM. If an intermittent open occurs in the thermocouple circuit, the capacitance could cause an erroneous on-scale reading.

The Model 2700 has an open thermocouple detection circuit. When enabled, a 10µA pulse of current is applied to the thermocouple before the start of each temperature measurement. If >12kΩ is detected (open thermocouple), the OVRFLW message will be displayed. If <12kΩ is detected, the current is turned off and a normal thermocouple temperature measurement is performed.

NOTE *Channel average cannot be used with thermocouple temperature measurements if open thermocouple detection is enabled.*

Thermistors

For thermistors, the temperature measurement range is -80°C to 150°C (0.01°C resolution). Thermister types that are supported include the 2.2kΩ, 5kΩ, and 10kΩ types.

The thermistor is a temperature sensitive resistor. It non-linearly changes resistance with changes in temperature. Most thermistors have a negative temperature coefficient. As temperature increases, the resistance decreases. The Model 2700 measures the resistance of the thermistor and calculates the temperature reading.

Of all the temperature transducers, the thermistor is the most sensitive. It can quickly detect minute changes in temperature. It is a good choice when measuring very small changes in temperature. The downside for this increased sensitivity is the loss of linearity. Since they are especially non-linear at high temperatures, it is best to use them for measurements below 100°C.

4-wire RTDs

For 4-wire RTDs, the temperature measurement range is -200°C to 630°C (0.01°C resolution). RTD types that are supported include D100, F100, PT385, and PT3916. A USER type is available to modify RTD parameters, such as the resistance at 0°C. The USER type can be enabled from the front panel, but the settings can only be changed using remote programming.

The RTD has a metal construction (typically platinum). The resistance of the RTD changes with change in temperature. The Model 2700 measures the resistance and calculates the temperature reading. When using default RTD parameters, the resistance of the RTD will be 100Ω at 0°C.

Of all the temperature transducers, the RTD exhibits the most stability and linearity. The Model 2700 performs the 4-wire measurement using offset compensated ohms. This provides the most accurate way to measure the low resistance of the RTD.

Connections

NOTE *When using the front panel inputs, the INPUTS switch must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

Thermocouple connections

Connections for thermocouples are shown in Figure 2-11. Thermocouples are color coded to identify the positive (+) and negative (-) leads (see Table 2-4). Note that the negative (-) lead for U.S. type T/Cs is red.

For front panel inputs, you need to use a simulated reference junction for thermocouple temperature measurements. An ice bath (as shown in Figure 2-11A) serves as an excellent cold junction since it is relatively easy to hold the temperature to 0°C. Notice that copper wires are used to connect the thermocouple to the Model 2700 input.

NOTE *The positive lead of the type T thermocouple is made of copper. Therefore, that lead can be connected directly to the input of the Model 7700. It does not have to be maintained at the simulated reference temperature (i.e., immersed in ice bath).*

For the Model 7700 switching module, you can also use a simulated reference junction as shown in Figure 2-11B, or you can connect the thermocouple wires directly to the screw terminals (internal reference junction) as shown in Figure 2-11C. Using a simulated reference junction may be inconvenient but it will provide more accurate temperature measurements (assuming the user enters a precise reference temperature).

With open thermocouple detection disabled, the Model 2700 can calculate the average temperature of two thermocouple channels using Channel Average (see Section 4 for details). As shown in Figure 2-11D, one thermocouple is connected to a primary channel (1 through 10), and the other thermocouple is connected to its paired channel (11 through 20). Channel 1 is paired to channel 11, channel 2 is paired to channel 12, and so on. Keep in mind that a simulated reference junction (i.e. ice bath) can instead be used for these thermocouple temperature measurements.

Figure 2-11
Thermocouple connections

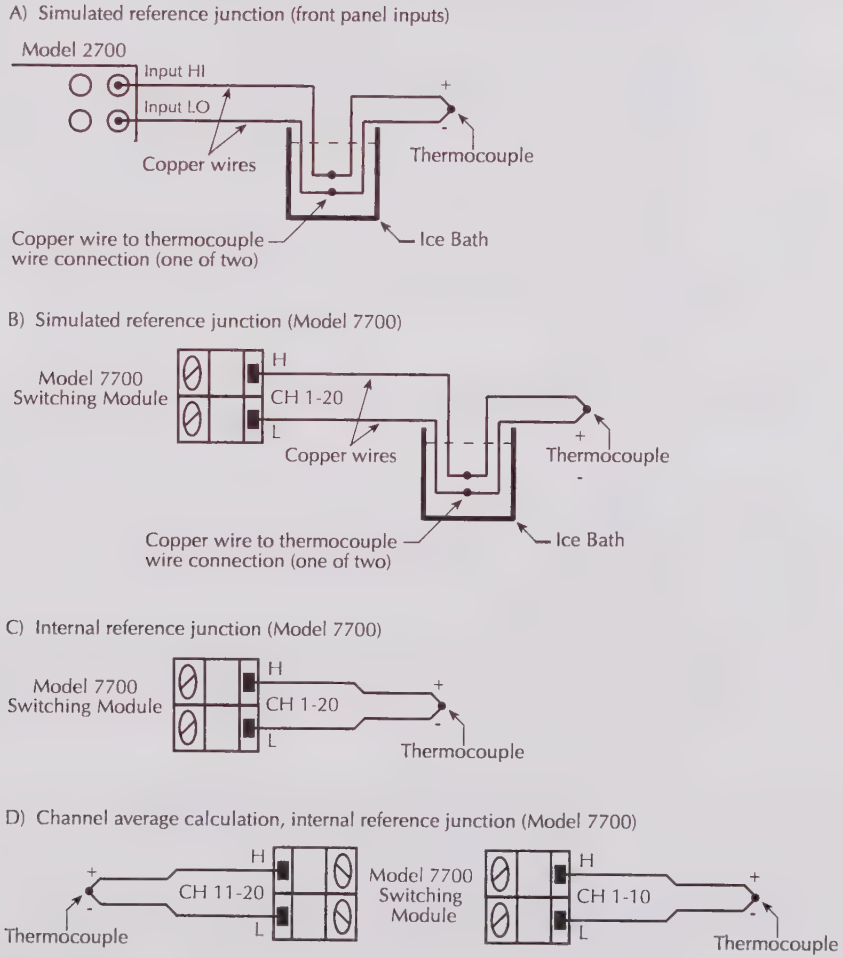


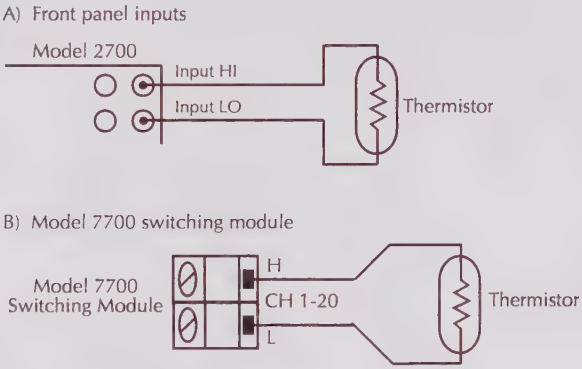
Table 2-4
Color codes - thermocouple wires

T/C Type		Positive (+)	Negative (-)	T/C Type		Positive (+)	Negative (-)
J	U.S.	White	Red	**E**	U.S.	Purple	Red
	British	Yellow	Blue		British	Brown	Blue
	DIN	Red	Blue		DIN	Red	Black
	Japanese	Red	White		Japanese	Red	White
	French	Yellow	Black		French	Yellow	Blue
K	U.S.	Yellow	Red	**R**	U.S.	Black	Red
	British	Brown	Blue		British	White	Blue
	DIN	Red	Green		DIN	Red	White
	Japanese	Red	White		Japanese	Red	White
	French	Yellow	Purple		French	Yellow	Green
N	U.S.	Orange	Red	**S**	U.S.	Black	Red
	British	—	—		British	White	Blue
	DIN	—	—		DIN	Red	White
	Japanese	—	—		Japanese	Red	White
	French	—	—		French	Yellow	Green
T	U.S.	Blue	Red	**B**	U.S.	Gray	Red
	British	White	Blue		British	—	—
	DIN	Red	Brown		DIN	Red	Gray
	Japanese	Red	White		Japanese	Red	Gray
	French	Yellow	Blue		French	—	—

Thermistor connections

A thermistor can be connected directly to the front panel inputs or to any of the 20 input channels of the Model 7700 switching module as shown in Figure 2-12.

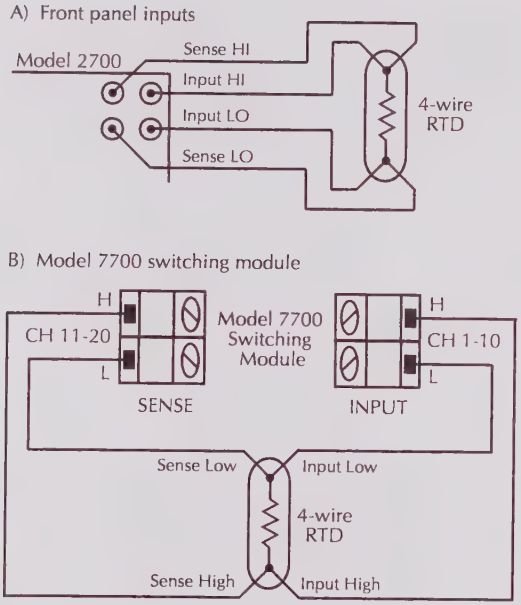
Figure 2-12
Thermistor connections



4-wire RTD connections

4-wire RTD connections to the Model 2700 are shown in Figure 2-13. For the Model 2700 switching module, paired channels are used to perform the 4-wire measurement. The two input leads of the RTD are connected to a primary channel (1 through 10), while the two sense leads are connected to its paired channel (11 through 20). Channel 1 is paired to channel 11, channel 2 is paired to channel 12, and so on.

Figure 2-13
4-wire RTD connections



Temperature measurement configuration

The Model 2700 is configured to measure temperature from the temperature measurement configuration menu. Use the following general rules to navigate through the menu structure:

- Press SHIFT and then SENSOR to enter the menu structure.
- Cursor position is indicated by a flashing menu item or parameter. Cursor position is controlled by the ◀ and ▶ keys.
- With the cursor on a menu item or parameter, use the ▲ and ▼ keys to scroll through the available options.
- A displayed menu item and parameter is selected by pressing ENTER.
- You can exit from the menu structure by pressing EXIT. However, any ENTERed selections will apply.

Thermocouple temperature measurement configuration

The steps to configure thermocouple measurements are provided in Table 2-5. After pressing SHIFT and then SENSOR, the menu starts at step 1 to select measurement units.

Each time you press ENTER to make a selection, the menu will automatically go to the next selection. After pressing ENTER for the last step, the instrument will return to the normal measurement state.

NOTE *If you select the internal (INT) reference junction for the front panel inputs or for a switching module that does not have an internal reference junction, the simulated (SIM) reference junction will instead be used and the "ERR" annunciator will turn on.*

Table 2-5
Thermocouple temperature measurement configuration

Step	Menu structure	Description
1	UNITS: C, F or K	Select temperature measurement units (°C, °F, or K).
2	SENS: TCOUPLE	Select the thermocouple transducer.
3	TYPE: J, K, T, E, R, S, B, or N	Select thermocouple type.
4	JUNC: SIM, INT, or EXT	Select the SIMulated, INTernal or EXTernal reference junction.
	SIM: 000°C to 065°C, 273K to 323K, or 032°F to 122°F	For the SIMulated reference junction, set the reference junction temperature. The displayed units depend on the present UNITS setting.
5	OPEN DET: Y or N	Enable (Y) or disable (N) the open thermocouple detector.

Thermistor temperature measurement configuration

The steps to configure thermistor measurements are provided in Table 2-6. After pressing SHIFT and then SENSOR, the menu starts at step 1 to select measurement units.

Each time you press ENTER to make a selection, the menu will automatically go to the next selection. After pressing ENTER for the last step, the instrument will return to the normal measurement state.

Table 2-6
Thermistor temperature measurement configuration

Step	Menu structure	Description
1	UNITS: C, F, or K	Select temperature measurement units (°C, °F, or K).
2	SENS: THRMSTR	Select the thermistor transducer.
3	TYPE: 2200Ω, 5000Ω, or 10kΩ	Select thermistor resistance.

4-wire RTD temperature measurement configuration

The Alpha, Beta, Delta, and Ω at 0°C parameters for the five basic RTD types are provided in Table 2-7. Note that these parameters can be modified using remote programming.

Table 2-7
RTD parameters

Type	Standard	Alpha	Beta	Delta	Ω at 0°C
PT101	ITS-90	0.003850	0.10863	1.49990	100Ω
D100	ITS-90	0.003920	0.10630	1.49710	100Ω
F100	ITS-90	0.003900	0.11000	1.49589	100Ω
PT385	IPTS-68	0.003850	0.11100	1.50700	100Ω
PT3916	IPTS-68	0.003916	0.11600	1.50594	100Ω

The steps to configure 4-wire RTD measurements are provided in Table 2-8. After pressing SHIFT and then SENSOR, the menu starts at step 1 to select measurement units.

Each time you press ENTER to make a selection, the menu will automatically go to the next selection. After pressing ENTER for the last step, the instrument will return to the normal measurement state.

NOTE *As shown in Table 2-8, you can select the USER sensor type, but you cannot change the USER parameters from the front panel. The parameters for the USER type can only be set using remote programming (see TEMPerature:FRTD commands in Table 2-9).*

Table 2-8
4-wire RTD temperature measurement configuration

Step	Menu Structure	Description
1	UNITS: C, F, or K	Select temperature measurement units (°C, °F, or K).
2	SENS: 4W-RTD	Select the 4-wire RTD transducer.
3	TYPE: PT100, D100, F100, PT385, PT3916, or USER	Select 4-wire RTD type.

Temperature measurement procedure

NOTE *Make sure the INPUTS switch is in the correct position. To use front panel inputs, it must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

1. If a switching channel is presently closed (displayed), press OPEN to open it.
2. Select the temperature measurement function by pressing TEMP.

3. Configure the temperature measurement as previously explained in "Temperature measurement configuration."
4. Connect the temperature transducer(s) to be measured.
5. If using a switching module, perform the following steps to close the desired channel. Keep in mind, that for 4-wire RTD measurements, you will close the primary (INPUT) channel (1 through 10). The channel that it is paired to will close automatically.
   a. Press the CLOSE key.
   b. Use ◀, ▶, ▲, and ▼ to key in the channel number and press ENTER. The previously closed channel(s) (if any) will open, and the specified channel (or channel pair) will close.

NOTE *While in the normal measurement state, you can use the ◀ and ▶ keys to close channels. In general, each key press will open the presently closed channel, and then close the next higher or lower channel.*

6. Observe the displayed reading.
7. To measure other switching channels, repeat steps 5 and 6.
8. When finished, press OPEN if there is a channel closed.

Frequency and period measurements

The Model 2700 can make frequency measurements from 3Hz to 500kHz on voltage ranges of 100mV, 1V, 10V, 100V, and 750V. Period (1 / frequency) measurements can be taken from 2µs to 333ms on the same voltage ranges as the frequency.

Input impedance: 1MΩ || <100pF, AC coupled.

The instrument uses the volts input to measure frequency. The AC voltage range can be changed with the RANGE ▲ and ▼ keys. The signal voltage must be greater than 10% of the full-scale range.

CAUTION **The voltage limit is subject to the 8×10^7V•Hz product.**

Trigger level

Frequency and period use a zero-crossing trigger, meaning that a count is taken when the frequency crosses the zero level. The Model 2700 uses a reciprocal counting technique to measure frequency and period. This method generates constant measurement resolution for any input frequency. The multimeter's AC voltage measurement section performs input signal conditioning.

Gate time

The gate time is the amount of time the Model 2700 uses to sample frequency or period readings. Use the RATE key to set the gate time; SLOW sets the gate time to 1.0 sec, MED sets it to 0.1 sec, and FAST sets it to 0.01 sec. For remote programming, the gate time can be set from 0.01 to 1.0 sec using the FREQuency:APERature, and PERiod:APERture commands (see Table 2-9). Note however, that if you set a gate time other than 1.0, 0.1, or 0.01 sec, the SLOW, MED, and FAST annunciators will be off.

The Model 2700 completes a reading when it receives its first zero-crossing after the gate time expires. In other words, the reading is completed 1/2 cycle after the gate time has expired. For example, to sample a 3Hz frequency, you may wait up to three seconds before the Model 2700 returns a reading.

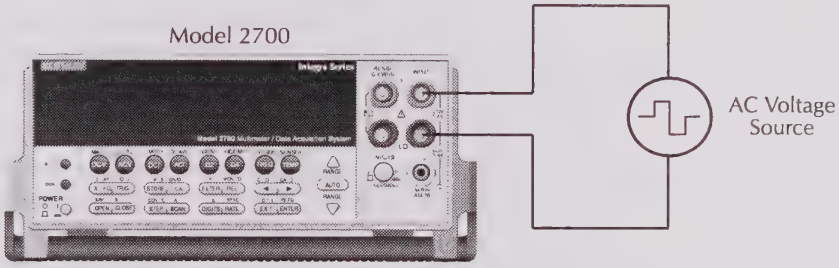
Connections

NOTE *When using the front panel inputs, the INPUTS switch must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

Front panel input

When using the front panel input terminals, connect the test leads to the INPUT HI and LO terminals as shown in Figure 2-14.

Figure 2-14
FREQ and PERIOD connections for front panel inputs



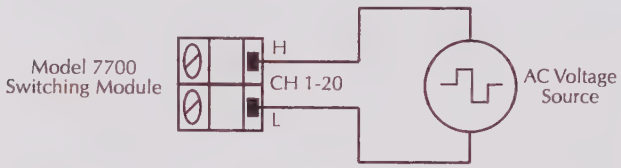
Input Impedance = 1MΩ in parallel with < 100pF

Caution: Maximum Input = 1000V peak, 8 x 10^7 V•Hz

Model 7700 switching module

Connections for the Model 7700 switching module are shown in Figure 2-15. For this 2-wire measurement, channels 1 through 20 can be used.

Figure 2-15
FREQ and PERIOD connections using Model 7700 switching module



Caution: Maximum = 300V peak or RMS, 8×10^7 V•Hz

Frequency and period measurement procedure

NOTE *Make sure the INPUTS switch is in the correct position. To use front panel inputs, it must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

1. If a switching channel is presently closed (displayed), press OPEN to open it.
2. Perform one of the following steps to select function:
   - Press FREQ to perform frequency measurements.
   - Press SHIFT and then FREQ to perform period measurements.
3. Use the RANGE ▲ and ▼ keys to select a measurement range consistent with the expected AC voltage. Details on range are provided in Section 3.
4. Apply the AC voltage(s) to be measured.

CAUTION **Do not apply more than maximum input levels indicated in Figure 2-14 and Figure 2-15 or instrument damage may occur.**

5. If using a switching module, perform the following steps to close the desired channel:
   a. Press the CLOSE key.
   b. Use ◀, ▶, ▲, and ▼ to key in the channel number and press ENTER. The previously closed channel (if there is one) will open, and the specified channel will close.

NOTE *While in the normal measurement state, you can use the ◀ and ▶ keys to close channels. In general, each key press will open the presently closed channel, and then close the next higher or lower channel.*

6. Observe the displayed reading. If the "OVERFLOW" message is displayed, select a higher range until a normal reading is displayed. Use the lowest possible range for the best resolution.
7. To measure other switching channels, repeat steps 5 and 6.
8. When finished, press OPEN if there is a channel closed.

Continuity testing

The Model 2700 can test continuity using the 1kΩ. After selecting continuity, you will be prompted to enter the threshold resistance level (1 to 1000Ω). When the measured circuit is below the set threshold level, the instrument will beep and display the resistance readings. When the measured circuit is above the threshold level, the message "OPEN" will be displayed.

NOTE *The reading rate for continuity is fixed at FAST (0.1 PLC).*

NOTE *Limits and digital outputs cannot be used when testing continuity with the continuity (CONT) function. If you need to use these operations, use the Ω2 function to test continuity.*

Connections

NOTE *When using the front panel inputs, the INPUTS switch must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

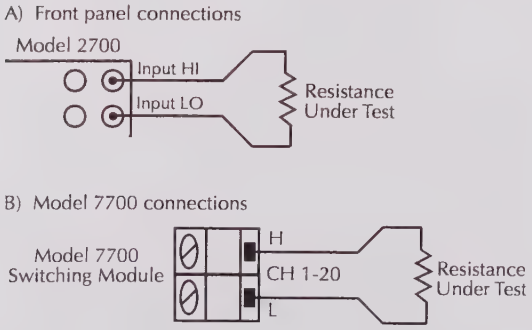
Front panel input

When using the front panel input terminals, connect the test leads to the INPUT HI and LO terminals as shown in Figure 2-16A.

Model 7700 switching module

Connections for the Model 7700 switching module are shown in Figure 2-16B. Since this is a 2-wire ohms measurement, channels 1 through 20 can be used.

Figure 2-16
Continuity connections



Note: Source current flows from input high to input low.

Continuity testing procedure

NOTE *Make sure the INPUTS switch is in the correct position. To use front panel inputs, it must be in the "F" (out) position. For switching modules, it must be in the "R" (in) position.*

1. Apply the resistance to be tested, and, if using a switching module, close the appropriate channel.
2. Press SHIFT and then CONT to display the present threshold LEVEL.
3. Use ◀, ▶, ▲, and ▼ to key in the desired level (1 to 1000W), and press ENTER.
   If the measurement is below the threshold level, the beeper will sound and the ohms reading will be displayed. If the measurement is above the threshold level, the message "OPEN" will be displayed.
4. To disable continuity testing, select a different function (i.e., press DCV).

NOTE *The beeper can be disabled using the :SYSTem:BEEPer:STATe OFF command. However, the beeper will automatically enable the next time the continuity testing function is selected.*

NOTE *Limits and digital outputs cannot be used when testing continuity with the continuity (CONT) function. If you need to use these operations, use the Ω2 function to test continuity.*

Remote programming - basic measurements

Basic measurement commands

Commands to perform basic measurements are listed in Table 2-9.

Table 2-9
Basic measurement commands

Commands	Description	Default	Ref
Select measurement function:[1]			
:FUNCtion <name> [, <clist>]	Select measurement function; <name = 'VOLTage[:DC]','VOLTage:AC', 'CURRent:DC', 'CURRent:AC', 'RESistance', 'FRESistance', 'CONTinuity', 'FREQuency', or 'PERiod'.	VOLT	A
DCV function:[1]			
:VOLTage[:DC]:IDIVider <b>	Enable/disable DCV input divider; <b> = ON or OFF.	OFF	
Ω4 function:[1]			
:FRESistance:OCOMpensated <b> [, <clist>]	Enable/disable offset compensated ohms.	OFF	B
TEMP function:[1]			
:TEMPerature:TRANsducer <name> [, <clist>]	Select temperature transducer; <name> = TCouple, FRTD or THERmistor.	TC	
:TEMPerature:TCouple:TYPE <type> [, <clist>]	Select T/C type; <type> = J, K, T, E, R, S, B, or N.	K	
:TEMPerature:TCouple:ODETect <b>	Enable/disable open thermocouple detector; <b> = ON or OFF.	OFF	
:TEMPerature:TCouple:RJUNction:RSELect <name> [, <clist>]	Select reference junction; <name> = SIMulated, INTernal or EXTernal.	SIM	C
:TEMPerature:TCouple:RJUNction:SIMulated <n> [, <clist>]	Set the simulated reference temperature; <n> = 0 to 50 (°C), 32 to 122 (°F) or 273 to 323 (K).	23°C	D
:TEMPerature:THERmistor <NRf> [, <clist>]	Set thermistor type in ohms; <NRf> = 1950 to 10050.	5000	
:TEMPerature:FRTD:TYPE <name> [, <clist>]	Select FRTD type; <name> = PT100, D100, F100, PT3916, PT385, or USER.	PT100	E
:TEMPerature:FRTD:RZERo <NRf> [, <clist>]	Specify constant for USER type; <NRf> = 0 to 10000.	100	

Table 2-9 (Continued)
Basic measurement commands

Commands	Description	Default	Ref
:TEMPerature:FRTD:ALPHa <NRf> [, <clist>]	Specify constant for USER type; <NRf> = 0 to 0.01.	0.00385	
:TEMPerature:FRTD:BETA <NRf> [, <clist>]	Specify constant for USER type; <NRf> = 0 to 1.00.	0.111	
:TEMPerature:FRTD:DELTa <NRf> [, <clist>]	Specify constant for USER type; <NRf> = 0 to 5.00.	1.507	
FREQ and PERIOD functions:[1]			
:FREQuency:THReshold:VOLTage:RANGe <n>	Select threshold voltage range; <n> = 0 to 1010.	10	F
:PERiod:THReshold:VOLTage:RANGe <n>	Select threshold voltage range; <n> = 0 to 1010.	10	F
:FREQuency:APERture <NRf> [, <clist>]	Set gate time for FREQ measurements in secs; <NRf> = 0.01 to 1.0.	1.0	G
:PERiod:APERture <NRf> [, <clist>]	Set gate time for PERIOD measurements in secs; <NRf> = 0.01 to 1.0.	1.0	G
CONT function:[1]			
:CONTinuity:THReshold <NRf>	Set continuity threshold in ohms; <NRf> = 1 to 1000.	10	
:SYSTem:BEEPer <b>	Enable/disable beeper; <b> = ON or OFF.	ON	
Set temperature measurement units:			
:UNIT:TEMPerature <name>	Set temperature units; <name> = (C, CEL, F, FAR, or K).		H
Triggering measurement(s):			I
[:SENSe[1]]:DATA?	Returns the last "raw" reading string.		
:INITiate:CONTinuous <b>	Enable/disable continuous initiation; <b> = ON or OFF.	Note 2	
:INITiate	Trigger one or more measurements.		
:READ?	Trigger and return readings(s).		
Channel list parameter: <clist> = (@SCH) where: S = Mainframe slot number (1 or 2) CH = Switching module channel number (must be 2 digits) Examples: (@101) = Slot 1, Channel 1 (@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3 (@101:110) = Slot 1, Channels 1 through 10			

[1]These measurement configuration commands are part of the SENSe1 subsystem. The root command for these commands, [:SENSe[1]], is optional and does not need to be included in the program message.
[2]The *RST default is OFF, and the :SYSTem:PRESet default is ON.

Reference

A. :FUNCtion <name> [, <clist>]

Note that the <name> parameters in the table are enclosed in single quotes (‘). However, double quotes (“) can instead be used. For example:

FUNC ‘VOLT:AC’ = FUNC “VOLT:AC”

B. :FRESistance:OCOMpensated <b> [, <clist>]

The instrument does not have to be on the Ω4 function to enable offset compensated ohms. When Ω4 is selected, offset compensated ohms will be enabled.

When using the <clist> parameter to configure a scan channel for offset compensated ohms, that channel must already be set for Ω4. If set for another function, a settings conflict (-221) will occur.

C. :TEMPerature:TCouple:RJUNction:RSELect <name> [, <clist>]

To use the EXTERnal reference junction, the scan channel (101 or 102) to be used used for the measurement must already be configured to use a thermister or 4-wire RTD transducer. Otherwise, a settings conflict error (-221) will occur. The :TEMPerature:TRANsducer command is used to select the transducer.

NOTE *The following command can instead be used to select the reference junction:*

:TEMPerature:RJUNction:RSELect <name> [, <clist>]

D. :TEMPerature:TCouple:RJUNction:SIMulated <n> [, <clist>]

The units for the simulated reference temperature depends on the present temperature measurement units as set by UNIT:TEMPerature (see Ref G).

NOTE *The following command can instead be used to set the simulated reference temperature:*

:TEMPerature:RJUNction:SIMulated <n> [, <clist>]

E. :TEMPerature:FRTD:RZERo <NRf> [, <clist>]
:TEMPerature:FRTD:ALPHa <NRf> [, <clist>]
:TEMPerature:FRTD:BETA <NRf> [, <clist>]
:TEMPerature:FRTD:DELTa <NRf> [, <clist>]

These commands are used to set the parameters for the USER RTD type. Note that the :RZERo command sets the “Ω at 0°C” parameter. When any of these commands are sent, the USER RTD type is automatically selected.

F. :FREQuency:THReshold:VOLTage:RANGe <n>
:PERiod:THReshold:VOLTage:RANGe <n>

These commands are used to specify the expected input level. The instrument will then automatically select the most sensitive current or voltage threshold range.

G. :FREQuency:APERture <NRf> [, <clist>]
:PERiod:APERture <NRf> [, <clist>]

The rate annunciators indicate the following aperture settings:

SLOW = 1 sec
MED = 0.1 sec
FAST = 0.01 sec

For all other aperture times, the rate annunciators are turned off.

H. :UNIT:TEMPerature <name>

To set temperature measurement units to °C, use the C or CEL parameter. For °F, use the F or FAR parameter. For Kelvin, use the K parameter.

I. [:SENSe[1]]:DATA?

:INITiate:CONTinuous <b>
:INITiate
:READ?

The DATA? command does not trigger a reading. It simply returns the last "raw" reading string. The reading reflects what is applied to the input. While the instrument is performing measurements, you can use this command to return the last reading. If the instrument is not performing measurements, DATA? will keep returning the same reading.

With continuous initiation disabled (INITiate:CONTinuous OFF), you can use the INITiate command to trigger one or more measurements. DATA? can then be used to return a reading. Note that sending INITiate while the instrument is performing measurements will cause error -213 (init ignored).

With continuous initiation disabled (INITiate:CONTinuous OFF), you can use the READ? command to trigger and return readings. The sample count determines the number of readings that are returned.

NOTE *You cannot use the :READ? command if sample count >1 and there are readings stored in the buffer (error -225, out of memory). Either set sample count to one (SAMPle:COUNt 1) or clear the buffer (TRACe:CLEar).*

Details on triggering are provided in Sections 7 and 12, while buffer operation is covered in Section 5.

Basic measurement programming examples

Example #1 — The following command sequence places the Model 2700 in a continuous trigger mode to measure ACV. Whenever DATA? is sent, the last reading measured reading will be sent to the computer when the Model 2700 is addressed to talk.

```
SYST:PRES                ' Continuous measurement mode (INIT:CONT ON).
FUNC 'VOLT:AC'           ' Select ACV function.
DATA?                    ' Request last measured reading.
```

Example #2 — The following command sequence places the Model 2700 in a one-shot trigger mode to measure offset compensated ohms. Whenever READ? is sent, a measurement will be triggered, and the measured reading will be sent to the computer when the Model 2700 is addressed to talk.

```
*RST                     ' One-shot measurement mode (INIT:CONT OFF).
FUNC 'FRES'              ' Select Ω4 function.
FRES:RANG 1e3            ' Select 1kΩ range.
FRES:OCOM ON             ' Enable offset compensated ohms.
READ?                    ' Trigger and return one reading.
```

Example #3 — The following command sequence places the Model 2700 in a one-shot trigger mode to perform a thermocouple temperature measurement at channel 101 (Model 7700 switching module installed in slot 1). With channel 101 closed, the INIT command triggers one measurement, and the DATA? command sends the measured reading to the computer when it is addressed to talk.

```
*RST                     ' One-shot measurement mode (INIT:CONT OFF).
FUNC 'TEMP'              ' Select TEMP function.
UNIT:TEMP F              ' Select °F TEMP units.
TEMP:TRAN TC             ' Select thermocouple transducer.
TEMP:TC:TYPE J           ' Select type J thermocouple.
TEMP:RJUN:RSEL SIM       ' Select simulated reference junction.
TEMP:RJUN:SIM 32         ' Set reference temperature to 32°F (ice point).
ROUT:CLOS (@101)         ' Close channel 101.
INIT                     ' Trigger one measurement.
DATA?                    ' Return measured reading.
```

Example #4 — The following commands configure scan channels 101, 102, and 121 of a Model 7700 installed in slot 1. When channel 101 is scanned, DCV will be selected. When channel 102 is scanned, Ω2 will be selected. When channel 121 is scanned, DCI will be selected.

```
FUNC 'VOLT',(@101)       ' Configure scan channel 101 for DCV.
FUNC 'RES',(@102)        ' Configure scan channel 102 for Ω2.
FUNC 'CURR',(@121)       ' Configure scan channel 121 for DCI.
```

3 Range, Digits, Rate, Bandwidth, and Filter

- **Range** — Provides details on measurement range selection. Includes the commands for remote programming.
- **Rate and bandwidth** — Provides details on integration rate and bandwidth (for AC measurements). Includes the commands for remote programming.
- **Digits** — Provides details on selecting display resolution. Includes the commands for remote programming.
- **Filter** — Provides details on filtering. Includes the commands for remote programming.

Range

The range setting is "remembered" by each measurement function. When you select a function, the instrument will return to the last range setting for that function.

Measurement ranges and maximum readings

The selected range affects both accuracy of the measurement as well as the maximum level that can be measured. The measurement ranges and maximum readings for all functions, except FREQ, PERIOD and TEMP, are listed in Table 3-1.

Input values that exceed the maximum readings cause the message "OVERFLOW" to be displayed.

Table 3-1
Measurement ranges and maximum readings

Function	Ranges	Maximum Reading
DCV	100mV, 1V, 10V, 100V, 1000V	±1010V
ACV	100mV, 1V, 10V, 100V, 750V	757.5V
DCI	200mA, 100mA, 1A, 3A	±3.1A
ACI	1A, 3A	3.1A
Ω2, Ω4	100Ω, 1kΩ, 10kΩ, 100kΩ, 1MΩ, 10MΩ, 100MΩ	120MΩ

FREQ and PERIOD — Frequency measurements from 3Hz to 500kHz, and period measurements from 2μs to 333μs can be made on the ACV ranges.

TEMP — There is no range selection for temperature measurements. Temperature measurements are performed on a single, fixed range. Depending on which type of sensor is being used, the maximum temperature readings range from –200°C to 1820°C. The Specifications (Appendix A) list the reading range for each sensor type.

Manual ranging

To change range, press the RANGE ▲ or ▼ key. The instrument changes one range per key press. The selected range is displayed for one second. Note that the manual range keys have no effect on temperature (TEMP).

If the instrument displays the "OVERFLOW" message on a particular range, select a higher range until an on-range reading is displayed. Use the lowest range possible without causing an overflow to assure best accuracy and resolution.

Auto ranging

To enable auto range, press the AUTO key. The AUTO annunciator turns on when auto ranging is selected. While auto ranging is enabled, the instrument automatically selects the best range to measure the applied signal. Auto ranging should not be used when optimum speed is required. Note that the AUTO key has no effect on temperature (TEMP).

Up-ranging occurs at 120% of range. The Model 2700 will down-range when the reading is ≤10% of nominal range.

To disable auto ranging, press AUTO. This will leave the instrument on the present range. You can also disable auto ranging by pressing the ▲ or ▼ key, however a range change may occur.

Scanning

When a simple scan is configured, the present function and range setting will apply to all channels in the scan. When an advanced scan is configured, each channel can have its own unique range setting. Details to configure and run a scan are provided in Section 6.

For remote programming, the <clist> parameter is used to configure channels for a scan.

Remote programming — range

Range commands

The commands to set range are listed in Table 3-2. Additional information on these commands follow the table.

NOTE *Query commands and some optional command words are not included in Table 3-2. All commands for the :SENSe subsystem are provided in Table 14-5.*

Table 3-2
Range commands

Commands*	Description	Default
[:SENSe[1]]	Optional root command for SENSe subsystem.	
:VOLTage[:DC]:RANGe <n> [, <clist>]	Select DCV range; <n> = 0 to 1010 (V).	1000
:VOLTage[:DC]:RANGe:AUTO <b> [, <clist>]	Control DCV auto range; <b> = ON or OFF.	ON
:VOLTage:AC:RANGe <n> [, <clist>]	Select ACV range; <n> = 0 to 757.5 (V).	750
:VOLTage:AC:RANGe:AUTO <b> [, <clist>]	Control ACV auto range; <b> = ON or OFF.	ON
:CURRent:DC:RANGe <n> [, <clist>]	Select DCI range; <n> = 0 to 3 (A).	3
:CURRent:DC:RANGe:AUTO <b> [, <clist>]	Control DCI auto range; <b> = ON or OFF.	ON
:CURRent:AC:RANGe <n> [, <clist>]	Select ACI range; <n> = 0 to 3 (A).	3
:CURRent:AC:RANGe:AUTO <b> [, <clist>]	Control ACI auto range; <b> = ON or OFF.	ON
:RESistance:RANGe <n> [, <clist>]	Select Ω2 range; <n> = 0 to 120e6 (Ω).	100e6
:RESistance:RANGe:AUTO <b> [, <clist>]	Control Ω2 auto range; <b> = ON or OFF.	ON
:FRESistance:RANGe <n> [, <clist>]	Select Ω4 range; <n> = 0 to 120e6 (Ω).	100e6
:FRESistance:RANGe:AUTO <b> [, <clist>]	Control Ω4 auto range; <b> = ON or OFF.	ON

Channel list parameter:
<clist> = (@SCH)
where: S = Mainframe slot number (1 or 2)
CH = Switching module channel number (must be 2 digits)
Examples: (@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

* The <clist> parameter is used to configure one or more channels for a scan. Each channel in the <clist> must be set to the function specified by the range command. If not, a conflict error (-221) will occur. For example, :VOLTage:AC:RANGe 1, (@101) is only valid if scan channel 101 is set for the ACV function.

Manual ranging

The range is selected by specifying the expected reading as an absolute value using the <n> parameter for the appropriate :RANGe command. The Model 2700 will then go to the most sensitive range for that expected reading. For example, if you expect a reading of approximately 3V, let the parameter (<n>) equal 3 to select the 10V range.

Auto ranging

The :RANGe:AUTO command is coupled to the command to select range manually (:RANGe <n>). When auto range is enabled, the parameter value for :RANGe <n> changes to the automatically selected range value. When auto range is disabled, the instrument remains at the selected range. When a valid :RANGe <n> command is sent, auto ranging disables.

Range programming examples

Example #1 — The following commands select range for DCV, Ω2 and DCI:

```
VOLT:RANG 0.5                    ' Select 1V range for DCV.
RES:RANG 2e3                     ' Select 10kΩ range for Ω2.
CURR:DC:RANG 0.1                 ' Select 100mA range for DCI.
```

Example #2 — The following command sequence configures channel 101 of the Model 7700 to select the 10VDC range when it is scanned.

```
FUNC 'VOLT',(@101)               ' Set 101 for DCV function.
VOLT:RANG 1.5,(@101)             ' Set 101 for 10V range.
```

Digits

The DIGITS key sets display resolution for the Model 2700 from 3½ to 6½ digits. From the front panel, setting digits for one function affects all the other functions. For example if you set DCV for 3½ digits, the other functions will also set to 3½ digits. For remote programming, each mainframe input function can have its own unique digits setting.

Digits has no effect on the remote reading format. The number of displayed digits does not affect accuracy or speed. Speed is set by the RATE key.

Setting display resolution — To set display resolution, press the DIGITS key until the desired number of digits is displayed.

Scanning

When a simple scan is configured, the present digits setting will apply to all channels in the scan. When an advanced scan is configured, each channel can have its own unique digits setting. Details to configure and run a scan are provided in Section 6.

For remote programming, the <clist> parameter is used to configure channels for a scan.

Remote programming — digits

Digits commands

The commands to control display resolution (digits) are listed in Table 3-3. Additional information on these commands follow the table.

NOTE *Query commands are not included in Table 3-3. All commands for the :SENSe subsystem are provided in Table 14-5.*

Table 3-3
Digits commands

Commands*	Description	Default
[:SENSe[1]]	Optional root command for SENSe subsystem:	
:VOLTage[:DC]:DIGits <n> [, <clist>]	Set # of digits for DCV; <n> = 4 to 7.	7
:VOLTage:AC:DIGits <n> [, <clist>]	Set # of digits for ACV; <n> = 4 to 7.	7
:CURRent:DC:DIGits <n> [, <clist>]	Set # of digits for DC1; <n> = 4 to 7.	7
:CURRent:AC:DIGits <n> [, <clist>]	Set # of digits for ACI; <n> = 4 to 7.	7
:RESistance:DIGits <n> [, <clist>]	Set # of digits for Ω2; <n> = 4 to 7.	7
:FRESistance:DIGits <n> [, <clist>]	Set # of digits for Ω4; <n> = 4 to 7.	7
:TEMPerature:DIGits <n> [, <clist>]	Set # of digits for TEMP; <n> = 4 to 7.	7
:FREQuency:DIGits <n> [, <clist>]	Set # of digits for FREQ; <n> = 4 to 7.	7
:PERiod:DIGits <n> [, <clist>]	Set # of digits for PERIOD; <n> = 4 to 7.	7

Channel list parameter:
<clist> = (@SCH)
where: S = Mainframe slot number (1 or 2)
CH = Switching module channel number (must be 2 digits)
Examples: (@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

* The <clist> parameter is used to configure one or more channels for a scan. Each channel in the <clist> must be set to the function specified by the digits command. If not, a conflict error (-221) will occur. For example, :VOLTage:AC:DIGits 4.5, (@101) is only valid if scan channel 101 is set for the ACV function.

Setting digits

Even though the parameters for the :DIGits command are expressed as integers (4 to 7), you can specify resolution using a real number. For example, to select 3½ digit resolution, let <n> = 3.5. Internally the instrument rounds the entered parameter value to the nearest integer.

As implied by the commands in Table 3-3, each mainframe input function can have its own unique digits setting.

Digits programming examples

Example #1 — The following commands set digits for DCV and ACI:

```
VOLT:DIG 5.5                    ' Set DCV to 5½ digits.
CURR:AC:DIG 4                   ' Set ACI to 3½ digits.
```

Example #2 — The following command sequence configures channels 101 through 110 of the Model 7700 to select 4½ digits when they are scanned.

```
FUNC 'RES' (@101:110)           ' Select Ω2 function.
RES:DIG 4.5,(@101:110)          ' Set scan channels to 4½ digits.
```

Rate and bandwidth

Rate

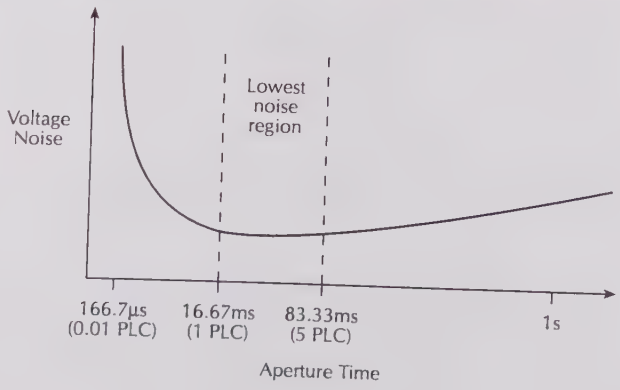
The RATE key sets the integration time (measurement speed) of the A/D converter, the period of time the input signal is measured (also known as aperture). The integration time affects the amount of reading noise, as well as the ultimate reading rate of the instrument.

The integration time is specified in parameters based on a number of power line cycles (NPLC), where 1 PLC for 60Hz is 16.67msec (1/60) and 1 PLC for 50Hz and 400Hz is 20msec (1/50).

In general, the fastest integration time (0.1 PLC from the front panel, 0.01 PLC from the bus) results in increased reading noise and fewer usable digits, while the slowest integration time (5 PLC from the front panel, 60 or 50 PLC from the bus) provides the best common-mode and normal-mode rejection. In-between settings are a compromise between speed and noise.

The Model 2700 has a parabola-like shape for its speed vs. noise characteristics and is shown in Figure 3-1. The Model 2700 is optimized for the 1 PLC to 5 PLC reading rate. At these rates (lowest noise region in graph), the Model 2700 will make corrections for its own internal drift and still be fast enough to settle a step response <100ms.

Figure 3-1
Speed vs. noise characteristics



The front panel RATE settings for all but the AC functions are explained as follow:

- FAST sets integration time to 0.1 PLC. Use FAST if speed is of primary importance (at the expense of increased reading noise and fewer usable digits).
- MEDium sets integration time to 1 PLC. Use MEDium when a compromise between noise performance and speed is acceptable.
- SLOW sets integration time to 5 PLC. SLOW provides better noise performance at the expense of speed.

For the AC functions (ACV, ACV dB, and ACI), the RATE key sets integration time and bandwidth. As listed in Table 3-4, FAST sets NPLC to 1, while the MEDium and SLOW NPLC settings are ignored (see "Bandwidth" for details).

Table 3-4
Rate and bandwidth settings

Function	Rate and bandwidth		
	Fast	Medium	Slow
DCV, DCI	NPLC=0.1	NPLC=1	NPLC=5
ACV, ACI	NPLC=1, BW=300	NPLC=X, BW=30	NPLC=X, BW=3
Ω2, Ω4	NPLC=0.1	NPLC=1	NPLC=5
FREQ, PERIOD	APER=0.01s	APER=0.1s	APER=1s
dB (ACV)	NPLC=1, BW=300	NPLC=X, BW=30	NPLC=X, BW=3
dB, (DCV)	NPLC=0.1	NPLC=1	NPLC=5
Continuity	NPLC=0.1	N/A	N/A

Notes:
NPLC = number of power line cycles.
BW = lower limit of bandwidth (in Hz).
APER = aperture in seconds.
N/A = not available.
X = setting ignored.

From the front panel, setting the rate for one function affects all the other functions. For example if you set DCV for medium speed, the other functions will also set to medium speed. For remote programming, each function can have its own unique rate setting (0.01 to 50 or 60 PLC).

NOTE *The RATE setting has no affect on continuity.*

Setting measurement speed — The RATE key is used to set measurement speed from the front panel. Simply press RATE until the desired speed annunciator (FAST, MED, or SLOW turns on.

NOTE *The Model 2700 uses internal references to calculate an accurate and stable reading. When the NPLC setting is changed, each reference must be updated to the new NPLC setting before a reading is generated. Therefore, frequent NPLC setting changes can result in slower measurement speed.*

Bandwidth

Bandwidth specifies the lowest frequency of interest for AC measurements. The RATE setting determines the bandwidth setting:

- SLOW — 3Hz to 300kHz
- MEDium — 30Hz to 300kHz
- FAST — 300Hz to 300kHz

When the Slow bandwidth (3Hz to 300kHz) is chosen, the signal goes through an analog RMS converter. The output of the RMS converter goes to a fast (1kHz) sampling A/D and the RMS value is calculated from 1200 digitized samples (1.2s).

When the Medium bandwidth (30Hz to 300kHz) is chosen, the same circuit is used. However, only 120 samples (120ms) are needed for an accurate calculation because the analog RMS converter has turned most of the signal to DC.

In the Fast bandwidth (300Hz to 300kHz), the output of the analog RMS converter (nearly pure DC at these frequencies) is simply measured at 1 PLC (16.6ms). For remote programming, the integration rate can be set from 0.01 PLC to 50 or 60 PLC.

Table 3-4 lists the front panel bandwidth settings for the AC measurement functions. For remote programming the FAST, MED, and SLOW annunciators are only lit when conditions in the table are met. In other case, the annunciators are turned off.

Scanning

When a simple scan is configured, the present rate or bandwidth setting will apply to all channels in the scan. When an advanced scan is configured, each channel can have its own rate or bandwidth setting. Details to configure and run a scan are provided in Section 6.

For remote programming, the <cllist> parameter is used to configure channels for a scan.

Remote programming — rate and bandwidth

Rate and bandwidth commands

The commands to set the integration rate and bandwidth are listed in Table 3-5. Additional information on these commands follow the table.

NOTE *Query commands are not included in Table 3-5. All commands for the :SENSe subsystem are provided in Table 14-5.*

Table 3-5
Rate and bandwidth commands

Commands [1]	Description	Default
Integration rate commands:		
[:SENSe[1]]	Optional root command for rate commands:	
:VOLTage[:DC]:NPLCycles <n> [, <clist>]	Set rate for DCV in PLCs; <n> = 0.01 to x. [2]	5.0
:VOLTage[:DC]:APERture <NRf> [, <clist>]	Set rate for DCV in secs; <NRf> = x to 1. [3]	(Note 4)
:VOLTage:AC:NPLCycles <n> [, <clist>]	Set rate for ACV in PLCs; <n> = 0.01 to xx. [2,5]	1.0
:VOLTage:AC:APERture <NRf> [, <clist>]	Set rate for ACV in secs; <NRf> = x to 1. [3,5]	(Note 4)
:CURRent:DC:NPLCycles <n> [, <clist>]	Set rate for DCI in PLCs; <n> = 0.01 to x. [2]	5.0
:CURRent:DC:APERture <NRf> [, <clist>]	Set rate for DCI in secs; <NRf> = x to 1. [3]	(Note 4)
:CURRent:AC:NPLCycles <n> [, <clist>]	Set rate for ACI in PLCs; <n> = 0.01 to x. [2,5]	1.0
:CURRent:AC:APERture <NRf> [, <clist>]	Set rate for ACI in secs; <NRf> = x to 1. [3,5]	(Note 4)
:RESistance:NPLCycles <n> [, <clist>]	Set rate for Ω2 in PLCs; <n> = 0.01 to x. [2]	5.0
:RESistance:APERture <NRf> [, <clist>]	Set rate for Ω2 in secs; <NRf> = x to 1. [3]	(Note 4)
:FRESistance:NPLCycles <n> [, <clist>]	Set rate for Ω4 in PLCs; <n> = 0.01 to x. [2]	5.0
:FRESistance:APERture <NRf> [, <clist>]	Set rate for Ω4 in secs; <NRf> = x to 1. [3]	(Note 4)
:TEMPerature:NPLCycles <n> [, <clist>]	Set rate for TEMP in PLCs; <n> = 0.01 to x. [2]	5.0
:TEMPerature:APERture <NRf> [, <clist>]	Set rate for TEMP in secs; <NRf> = x to 1. [3]	(Note 4)
Bandwidth commands:		
[:SENSe[1]]	Optional root command for bandwidth commands:	
:VOLTage:AC:DETector:BANDwidth <NRf> [, <clist>]	Set AC bandwidth for ACV in Hertz; <NRf> = 3 to 3e5. [6]	30
:CURRent:AC:DETector:BANDwidth <NRf> [, <clist>]	Set AC bandwidth for ACI in Hertz; <NRf> = 3 to 3e5. [6]	30

Channel list parameter:
<clist> = (@SCH)
where: S = Mainframe slot number (1 or 2)
CH = Switching module channel number (must be 2 digits)
Examples: (@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

Notes:
[1] The <clist> parameter is used to configure one or more channels for a scan. Each channel in the <clist> must be set to the function specified by the command. If not, a conflict error (-221) will occur. For example, :RESistance:NPLCycles 1, (@101) is only valid if scan channel 101 is set for the Ω2 function.
[2] For 60Hz line power, x = 60. For 50Hz line power, x = 50.
[3] For 60Hz line power, x = 1.67e-4. For 50Hz line power, x = 2e-4.
[4] For 60Hz line power, the default is 16.67msec. For 50Hz line power, the default is 20msec.
[5] Commands to set rate for ACV and ACI are only valid if bandwidth is set to 300 (300Hz to 300kHz). See "Rate and bandwidth conflict error" below for details.
[6] The instrument will actually accept a parameter value up to 10e6, but it will default to 3e5.

Aperture

Aperture is a different way to specify the integration rate. As previously explained, 1 PLC sets the integration rate to 16.67msec (assuming 60Hz line power). You can instead use an :APERture command as follows to set the same integration rate:

:APERture 16.67e-3

Bandwidth

There are three bandwidth settings for ACV and ACI measurements; 3 (3Hz to 300kHz), 30 (30Hz to 300kHz) and 300 (300Hz to 300kHz). To achieve the best accuracy for ACV and ACI measurements, use the bandwidth setting that best reflects the frequency of the input signal. For example, if the input signal is 40Hz, then a bandwidth setting of 30 should be used.

To set bandwidth, simply specify (approximately) the frequency of the input signal. The instrument will automatically set the bandwidth as follows:

<NRf>	= 3 to 29	3Hz to 300kHz
	= 30 to 299	30Hz to 300kHz
	= 300 to 300e3	300Hz to 300kHz

NOTE *A rate command (:NPLCycles or :APERture) for ACV and ACI is only valid if the bandwidth for that AC function is set to 300 (300Hz to 300kHz). See "Rate and bandwidth conflict error" below for details.*

Rate and bandwidth conflict error

For bandwidth settings of 3 and 30, the normal A/D conversion method is not used for ACV and ACI measurements. Therefore, integration rate commands (:NPLCycles and :APERture) for these bandwidth settings will cause a settings conflict error (-221) and not be executed.

For a bandwidth setting of 300, the normal A/D conversion method is used, therefore the integration rate commands can be used.

The default bandwidth setting is 30 for both ACV and ACI. If you want to set an integration rate for an AC function, you will have to first set the bandwidth to 300.

Rate and bandwidth programming examples

Example #1 — The following command sequence sets ACV rate to 5 PLC. In order to set rate for an AC function, bandwidth must first be set to 300:

```
VOLT:AC:DET:BAND 300                    ' Set ACV bandwidth to 300.
VOLT:AC:NPLC 5                          ' Set ACV rate to 5 PLC.
```

NOTE *One must set VOLT:AC:DET:BAND to 300 before VOLT:AC:NPLC xxx can be sent.*

Example #2 — The following command sequence configures channels 101 and 103 of the Model 7700 to set integration rate to 6 PLC when they are scanned.

```
FUNC 'VOLT' (@101, 103)                 ' Select DCV function.
VOLT:NPLC 6,(@101, 103)                 ' Set rate to 6 PLC.
```

Filter

The digital filter is used to stabilize noisy measurements. The displayed, stored or transmitted reading is a windowed-average of a number of reading conversions (from 1 to 100).

The filter setup is "remembered" and can be unique for each measurement function (DCV, ACV, DCI, ACI, Ω2, Ω4, and TEMP). When you select a function, the instrument will return to the last filter setup for that function.

Filter characteristics

In general, the digital filter places a specified number of A/D conversions (Filter Count) into a memory stack. These A/D conversions must occur consecutively within a selected reading window (Filter Window). The readings in the stack are then averaged to yield a single filtered reading. The stack can be filled in two ways (Filter Type); moving or repeating. The moving filter keeps adding and removing a single A/D conversion from the stack before taking the average, while the repeating filter only averages a stack that is filled with new A/D conversions.

Details on digital filter characteristics are provided as follow:

Filter count — The filter count specifies how many consecutive A/D conversions (within the filter window) to place in the memory stack. When the stack is full, the A/D conversions are averaged to calculate the final filtered reading. The filter count can be set from 1 to 100. Note that with a filter count of 1, no averaging is done. However, only readings within the filter window will be displayed, stored or transmitted.

NOTE *While the filter processes readings, the FILT annunciator blinks. Readings that are being displayed while the FILT annunciator blinks are not final filtered readings. When the FILT annunciator stops blinking, the filter has settled.*

Filter window — The digital filter uses a window to control filter threshold. As long as the input signal remains within the selected window, A/D conversions continue to be placed in the stack. If the signal changes to a value outside the window, the filter resets, and the filter starts processing again starting with a new initial conversion value from the A/D converter.

The five window selections from the front panel are 0.01%, 0.1%, 1%, 10% of range and NONE (no window). For remote programming, the window can be set to any value from 0.01% to 10% or NONE.

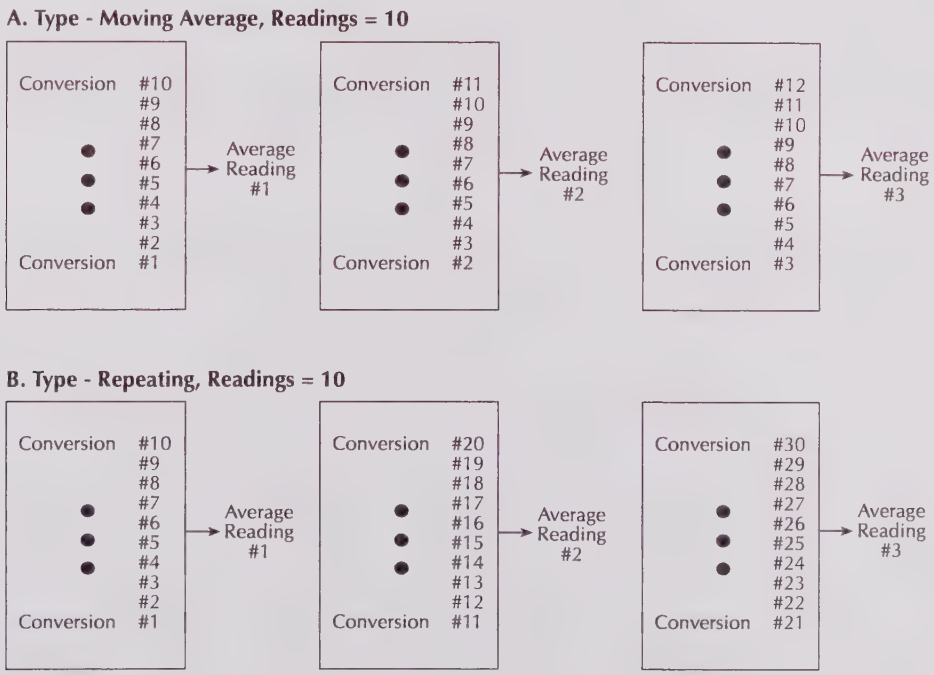
For voltage, current, and resistance, the filter window is expressed as a percent of range. For example, on the 10V range, a 10% window means that the filter window is ±1V. For temperature, the filter window is expressed as a percent of the maximum temperature reading. The maximum temperature depends on which thermocouple is being used. For example, for a Type J thermocouple, the maximum reading is 760°C; a 10% window means that the filter window is ±76°C.

Filter type — There are two digital filter types; moving and repeating. The moving average filter uses a first-in, first-out stack. When the stack becomes full, the measurement conversions are averaged, yielding a reading. For each subsequent conversion placed in the stack, the oldest conversion is discarded, and the stack is re-averaged, yielding a new reading. This process is depicted in Figure 3-2A.

For the repeating filter, the stack is filled and the conversions are averaged to yield a reading. The stack is then cleared and the process starts over (see Figure 3-2B). The repeating filter is used for scanning so readings from other channels are not averaged with the present channel.

NOTE *The moving filter cannot be used when scanning. If a scan channel is set up to use the moving filter, the filter will not turn on. Scanning is covered in Section 6.*

Figure 3-2
Moving and repeating filters



Filter example

Filter Type - Moving
Filter Window = 0.01%of range
Filter Count = 10
Filter State = On

Ten readings fill the stack to yield a filtered reading. Now assume the next reading (which is the 11^{th}) is outside the window. A reading will be processed (displayed); however, the stack will be loaded with that same reading. Each subsequent valid reading will then displace one of the loaded readings in the stack. The FILT annunciator will flash until 10 new readings fill the stack.

NOTE *Bit 8 of the Operation Event Status Register sets when the filter window has properly settled (or the filter is disabled). See "Status Structure" in Section 10 for details.*

Filter control and configuration

The FILTER key toggles the state of the Filter. When the Filter is enabled, the FILT annunciator is on. The FILT annunciator will flash when the filter is not settled. When disabled, the FILT annunciator is off. The filter can be configured while it is enabled or disabled.

Perform the following steps to configure the Filter:

1. Select the desired function.
2. Press SHIFT and then TYPE. The present WINDOW setting will be displayed.
3. Use the RANGE ▲ or ▼ key to display the desired window setting (0.01%, 0.1%, 1%, 10%, or NONE), and press ENTER.
4. Use the ◀, ▶, ▲, and ▼ keys to display the number of readings to filter (1 to 100), and press ENTER.
5. Use the ▲ or ▼ key to display the desired filter type (moving or repeating), and press ENTER. The filter turns on and the instrument returns to the normal measurement state.

NOTES *While the Filter is enabled (FILT annunciator on), changes to the configuration take effect as soon as they are made. With Filter disabled, (FILT annunciator off), changes to the configuration take place when the Filter is enabled.*

While the filtering operation is in progress, the FILT annunciator blinks. Readings will continue to be processed (i.e., displayed, stored, sent over the bus), but they could be questionable. When the FILT annunciator stops blinking, the filter has settled.

Changing function or range causes the Filter to reset. The Filter then assumes the state (enabled or disabled) and configuration for that function or range.

Scanning

The moving filter cannot be used when scanning. A scan channel cannot be configured to use the moving filter. Also, the filter window is not used when scanning.

When a simple scan is configured, the present filter count and state will apply to all channels in the scan. The window setting is ignored (effectively set to NONE), and if the moving filter is selected, the filter will not enable when the scan is run.

For the advanced scan, filter state (on or off) and count can be set for each channel. You cannot set unique filter count, type, and window settings from the advanced scan setup menu.

For remote programming, the <clist> parameter is used to set filter count and state for each channel in the scan. You cannot set unique filter type and window settings.

NOTE *Details on configuring a scan using filtering in a scan are provided in Section 6.*

Remote programming — filter

Filter commands

The filter commands are listed in Table 3-6. Additional information on these commands follow the table.

NOTE *Query commands are not included in Table 3-6. All commands for the :SENSe subsystem are provided in Table 14-5.*

Table 3-6
Filter commands

Commands [1]	Description	Default
DCV filter commands:		
[:SENSe[1]]	Optional root command for DCV filter commands:	
:VOLTage[:DC]:AVERage:TCONtrol <name>	Select filter type; <name> = MOVing or REPeat.	(Note 2)
:VOLTage[:DC]:AVERage:WINDow <NRf>	Set filter window in %; <NRf> = 0 to 10.	0.1
:VOLTage[:DC]:AVERage:COUNt <n> [, clist]	Specify filter count; <n> = 1 to 100.	10
:VOLTage[:DC]:AVERage:STATe <b> [, clist]	Enable or disable the filter.	(Note 3)
ACV filter commands:		
[:SENSe[1]]	Optional root command for ACV filter commands:	
:VOLTage:AC:AVERage:TCONtrol <name>	Select filter type; <name> = MOVing or REPeat.	(Note 2)
:VOLTage:AC:AVERage:WINDow <NRf>	Set filter window in %; <NRf> = 0 to 10.	0.1
:VOLTage:AC:AVERage:COUNt <n> [, clist]	Specify filter count; <n> = 1 to 100.	10
:VOLTage:AC:AVERage:STATe <b> [, clist]	Enable or disable the filter.	(Note 3)
DCI filter commands:		
[:SENSe[1]]	Optional root command for DCI filter commands:	
:CURRent:DC:AVERage:TCONtrol <name>	Select filter type; <name> = MOVing or REPeat.	(Note 2)
:CURRent:DC:AVERage:WINDow <NRf>	Set filter window in %; <NRf> = 0 to 10.	0.1
:CURRent:DC:AVERage:COUNt <n> [, clist]	Specify filter count; <n> = 1 to 100.	10
:CURRent:DC:AVERage:STATe <b> [, clist]	Enable or disable the filter.	(Note 3)
ACI filter commands:		
[:SENSe[1]]	Optional root command for ACI filter commands:	
:CURRent:AC:AVERage:TCONtrol <name>	Select filter type; <name> = MOVing or REPeat.	(Note 2)
:CURRent:AC:AVERage:WINDow <NRf>	Set filter window in %; <NRf> = 0 to 10.	0.1
:CURRent:AC:AVERage:COUNt <n> [, clist]	Specify filter count; <n> = 1 to 100.	10
:CURRent:AC:AVERage:STATe <b> [, clist]	Enable or disable the filter.	(Note 3)

Table 3-6 (Continued)
Filter commands

Commands [1]	Description	Default
Ω2 filter commands:		
[:SENSe[1]]	Optional root command for Ω2 filter commands:	
:RESistance:AVERage:TCONtrol <name>	Select filter type; <name> = MOVing or REPeat.	(Note 2)
:RESistance:AVERage:WINDow <NRf>	Set filter window in %; <NRf> = 0 to 10.	0.1
:RESistance:AVERage:COUNt <n> [, clist]	Specify filter count; <n> = 1 to 100.	10
:RESistance:AVERage:STATe <b> [, clist]	Enable or disable the filter.	(Note 3)
Ω4 filter commands:		
[:SENSe[1]]	Optional root command for Ω4 filter commands:	
:FRESistance:AVERage:TCONtrol <name>	Select filter type; <name> = MOVing or REPeat.	(Note 2)
:FRESistance:AVERage:WINDow <NRf>	Set filter window in %; <NRf> = 0 to 10.	0.1
:FRESistance:AVERage:COUNt <n> [, clist]	Specify filter count; <n> = 1 to 100.	10
:FRESistance:AVERage:STATe <b> [, clist]	Enable or disable the filter.	(Note 3)
TEMP filter commands:		
[:SENSe[1]]	Optional root command for TEMP filter commands:	
:TEMPerature:AVERage:TCONtrol <name>	Select filter type; <name> = MOVing or REPeat.	(Note 2)
:TEMPerature:AVERage:WINDow <NRf>	Set filter window in %; <NRf> = 0 to 10.	0.1
:TEMPerature:AVERage:COUNt <n> [, clist]	Specify filter count; <n> = 1 to 100.	10
:TEMPerature:AVERage:STATe <b> [, clist]	Enable or disable the filter.	(Note 3)

Channel list parameter:
<clist> = (@SCH)
where: S = Mainframe slot number (1 or 2)
CH = Switching module channel number (must be 2 digits)
Examples: (@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

Notes:
[1] The <clist> parameter is used to configure one or more channels for a scan. Each channel in the <clist> must be set to the function specified by the filter command. If not, a conflict error (-221) will occur. For example, :VOLTage:AVERage:STATe ON, (@101) is only valid if scan channel 101 is set for the DCV function.
[2] REPeat is the *RST default, and MOVing is the :SYSTem:PRESet default. From the front panel, the factory default is MOVing.
[3] OFF is the *RST default, and ON is the :SYSTem:PRESet default.

Filter programming examples

Example #1 — The following command sequence configures filtering for the DCI function:

```
CURR:DC:TCON MOV                    ' Select the moving filter.
CURR:DC:AVER:WIND 0.01              ' Set filter window to 0.01%.
CURR:DC:AVER:COUN 10                ' Set to filter 10 readings.
CURR:DC:AVER ON                     ' Enable filter.
```

Example #2 — The following command sequence configures channels 101 through 115 of the Model 7700 to use the repeat filter when they are scanned.

```
FUNC 'VOLT'                         ' Select DCV function.
VOLT:AVER:TCON REP                  ' Select the repeating filter.
VOLT:AVER:COUN 20,(@101:115)        ' Set to filter 20 readings.
VOLT:AVER ON,(@101:115)             ' Enable filter.
```

4
Relative, Math, Ratio, Channel Average, and dB

- **Relative** — Explains how to null an offset or establish a baseline value. Includes the commands for remote programming.
- **Math** — Covers the two basic math operations; mX+b and percent. Includes the commands for remote programming.
- **Ratio and channel average** — Explains how to use these calculations to display the ratio or average of two switching channels.
- **dB** — Explains how to use remote programming to configure the instrument to perform DCV dB and ACV dB measurements.

WARNING **When using these functions, the display may indicate a non-hazardous voltage, but hazardous voltage may be present on the input connectors.**

Relative

The rel (relative) function can be used to null offsets or subtract a baseline reading from present and future readings. When rel is enabled, the instrument uses the present reading as a relative value. Subsequent readings will be the difference between the actual input value and the rel value.

You can define a rel value for each function. Once a rel value is established for a measurement function, the value is the same for all ranges. For example, if 50V is set as a rel value on the 100V range, the rel is also 50V on the 1000V, 10V, 1V, and 100mV ranges.

Therefore, when you perform a zero correction by enabling REL, the displayed offset becomes the reference value. Subtracting the offset from the actual input zeroes the display, as follows:

Actual Input – Reference = Displayed Reading

A rel value can be as large as the highest range.

Selecting a range that cannot accommodate the rel value does not cause an overflow condition, but it also does not increase the maximum allowable input for that range. For example, on the 10V range, the Model 2700 still overflows for a 12V input.

Basic operation

NOTE *If using switching module inputs, make sure the front panel INPUTS switch is set to the REAR position (in). If using the front panel inputs, the switch must be in the FRONT position (out).*

1. Select the desired measurement function and an appropriate range setting.
2. Apply the signal to be relayed to a switching channel input or to the front panel inputs.

NOTE *For the Model 7700 switching module, channels 21 and 22 are available for DCI and ACI. Channels 1 through 20 are available for all other functions.*

3. If using a switching module, use the ◀ or ▶ key to select (close) the input channel. If using the front panel inputs (FRONT inputs selected), it does not matter if a switching channel is closed.
4. Press the REL key to set the rel value. The display will zero and the REL annunciator will turn on.
5. Apply the signal to be measured.

Pressing REL a second time disables rel.

You can input a rel value manually using the mX+b function. Set M for 1 and B for any value you want. The mX+b function is covered in this section (see "Math").

Scanning

When a simple scan is configured, the present rel setting will apply to all channels in the scan. When an advanced scan is configured, each channel can have its own unique rel setting. Details to configure and run a scan are provided in Section 6.

For an advanced scan, the following general procedure shows how to configure a scan channel to use rel:

1. While in the normal measurement state, select the appropriate function and close the appropriate channel. For example, if scan channel 101 is going to be configured for DCV and use rel, select DCV and close channel 101.
2. Apply the DCV signal to be rel'ed to the closed channel. This could be an offset or a baseline level.
3. Press the REL key to enable rel (REL annunciator on). The input signal level is used as the rel value.
4. When configuring the advanced scan (as explained in Section 6), select the desired channel, press DCV and then press REL (REL annunciator on).

When the channel is scanned, rel will enable using the rel value established in step 3.

For remote programming, the <clist> parameter is used to configure channels for a scan.

Remote programming — rel

Rel commands

The rel commands to set range are listed in Table 4-1. Additional information on these commands follow the table.

NOTE *Query commands are not included in Table 4-1. All commands for the :SENSe subsystem are provided in Table 14-5.*

Table 4-1
Rel commands

Commands[1]	Description	Default
Rel commands for DCV:		
[:SENSe[1]]	Optional root command for DCV rel.	
:VOLTage[:DC]:REFerence <n> [, <clist>]	Specify rel value; <n> = -1010 to 1010 (V).	0
:VOLTage[:DC]:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:VOLTage[:DC]:REFerence:ACQuire	Use input signal as rel value.	
Rel commands for ACV:		
[:SENSe[1]]	Optional root command for ACV rel.	
:VOLTage:AC:REFerence <n> [, <clist>]	Specify rel value; <n> = -757.5 to 757.5 (V).	0
:VOLTage:AC:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:VOLTage:AC:REFerence:ACQuire	Use input signal as rel value.	
Rel commands for DCI:		
[:SENSe[1]]	Optional root command for DCI rel.	
:CURRent:DC:REFerence <n> [, <clist>]	Specify rel value; <n> = -3.1 to 3.1 (A).	0
:CURRent:DC:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:CURRent:DC:REFerence:ACQuire	Use input signal as rel value.	
Rel commands for ACI:		
[:SENSe[1]]	Optional root command for ACI rel.	
:CURRent:AC:REFerence <n> [, <clist>]	Specify rel value; <n> = -3.1 to 3.1 (A).	0
:CURRent:AC:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:CURRent:AC:REFerence:ACQuire	Use input signal as rel value.	
Rel commands for Ω2:		
[:SENSe[1]]	Optional root command for Ω2 rel.	
:RESistance:REFerence <n> [, <clist>]	Specify rel value; <n> = -1200e6 to 120e6 (Ω).	0
:RESistance:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:RESistance:REFerence:ACQuire	Use input signal as rel value.	

Table 4-1 (Continued)
Rel commands

Commands[1]	Description	Default
Rel commands for Ω4:		
[:SENSe[1]]	Optional root command for Ω4 rel.	
:FRESistance:REFerence <n> [, <clist>]	Specify rel value; <n> = -1200e6 to 120e6 (Ω).	0
:FRESistance:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:FRESistance:REFerence:ACQuire	Use input signal as rel value.	
Rel commands for TEMP:[2]		
[:SENSe[1]]	Optional root command for TEMP rel.	
:TEMPerature:REFerence <n> [, <clist>]	Specify rel value; <n> = -200 to 1820 (°C).	0
:TEMPerature:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:TEMPerature:REFerence:ACQuire	Use input signal as rel value.	
Rel commands for FREQ:		
[:SENSe[1]]	Optional root command for FREQ rel.	
:FREQuency:REFerence <n> [, <clist>]	Specify rel value; <n> = 0 to 1.5e7 (Hz).	0
:FREQuency:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:FREQuency:REFerence:ACQuire	Use input signal as rel value.	
Rel commands for PERIOD:		
[:SENSe[1]]	Optional root command for PERIOD rel.	
:FREQuency:REFerence <n> [, <clist>]	Specify rel value; <n> = 0 to 1 (sec).	0
:FREQuency:REFerence:STATe <b> [, <clist>]	Enable/disable rel; <b> = ON or OFF.	OFF
:FREQuency:REFerence:ACQuire	Use input signal as rel value.	

Channel list parameter:
<clist> = (@SCH)
where: S = Mainframe slot number (1 or 2)
CH = Switching module channel number (must be 2 digits)
Examples: (@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

* The <clist> parameter is used to configure one or more channels for a scan. Each channel in the <clist> must be set to the function specified by the rel (reference) command. If not, a conflict error (-221) will occur. For example, :VOLTage:AC:REFerence 1, (@101) is only valid if scan channel 101 is set for the ACV function.

"Pressing REL" using rel commands

When the front panel REL key is pressed, the displayed reading is used as the rel value. Subsequent readings are then the result of the actual input value and the rel value.

The :REFerence:ACQuire and :REFerence:STATe ON commands (in that order) can be used to "press" the REL key. For example, the following command sequence is the equivalent of pressing the REL key while on the DCV function:

```
VOLT:REF:ACQ                    ' Acquire reading as rel value.
VOLT:REF:STAT  ON               ' Enable rel.
```

Setting rel values

The :REFerence <n> command specifies the rel value for the specified function, while the :ACQuire command uses the input signal as the rel value. The :ACQuire command is typically used to zero the display. For example, if the instrument is displaying a 1µV offset, sending :ACQuire and enabling rel (:STATe ON) zeroes the display.

The :ACQuire command is only functional if the instrument is on the specified function. For example. If the instrument is on the DCV function, the only valid acquire command is :VOLT:DC:REF:ACQ. Also, if the instrument is overflowed ("OVERFLOW"), or a reading has not been triggered ("------"), an execution error (-200) occurs when :ACQuire is sent.

The :REFerence <n> command is coupled to the :ACQuire command. When a rel value is set using :REFerence <n>, the :REFerence? query command returns the programmed value. When rel is set using :ACQuire, the :REFerence? query command returns the acquired rel value.

Rel programming examples

Example #1 — The following command sequence zeroes the display for DCV.

```
FUNC 'VOLT'                     ' Select DCV.
VOLT:REF:ACQ                    ' Use input level as rel value for DCV.
VOLT:REF:STAT ON                ' Enable rel.
```

Example #2 — The following command sequence configures channel 101 of the Model 7700 to enable rel and use a 1V rel value when it is scanned.

```
FUNC 'VOLT',(@101)              ' Select DCV for channel 101.
VOLT:REF 1,(@101)               ' Set 1V rel value.
VOLT:REF:STAT ON,(@101)         ' Enable rel.
```

Example #3 — The following command sequence configures channel 101 of the Model 7700 to zero correct the DCV input when it is scanned.

```
FUNC 'VOLT',(@101)
ROUT:CLOS (@101)
VOLT:REF:ACQ (@101)
VOLT:REF:STAT ON,(@101)
```

Math

mX+b

This math operation lets you manipulate normal display readings (X) mathematically according to the following calculation.

$Y = mX + b$

where; X is the normal display reading
m and b are the user-entered constants for scale factor and offset
Y is the displayed result

mX+b configuration

1. Press SHIFT and then MATH to display the math menu.
2. Press the RANGE ▲ and ▼ key to display "mX+B", and press ENTER to display the present scale factor:

   M: +1.000000 ▲ (factory default)

3. Key in the scale factor value. The ◀ and ▶ keys control cursor position, and the ▲ and ▼ keys increment/decrement the digit value. To change range, place the cursor on the multiplier and use the ▲ and ▼ keys (m = ×0.001, ▲ = ×1, K = ×1000, and M = ×1,000,000). With the cursor on the polarity sign, the ▲ and ▼ keys toggle polarity.
4. Press ENTER to enter the M value and display the offset (B) value:

   B: +00.00000 m (factory default)

5. Key in the offset value.
6. Press ENTER to enter the B value and display the one-character units designator:

   UNITS: X (factory default)

7. Use the cursor keys and the ▲ or ▼ key if you wish to change the units designator. The character can be any letter in the alphabet (A through Z), the degree symbol (°) or the ohms symbol (Ω).
8. Press ENTER. The MATH annunciator will turn on, and the result of the calculation will be displayed. Note that the calculation will be applied to all measurement functions.
9. To disable mX+b, again press SHIFT and then mX+b. The MATH annunciator will turn off.

mX+b rel

The mX+b function can be used to manually establish a rel value. To do this, set the scale factor (M) to 1 and set the offset (B) to the rel value. Each subsequent reading will be the difference between the actual input and the rel value (offset).

Percent

This math function determines percent deviation from a specified reference value. The percent calculation is performed as follows:

$$\text{Percent} = \frac{\text{Input} - \text{Reference}}{\text{Reference}} \times 100\%$$

where; Input is the normal display reading
Reference is the user entered constant
Percent is the displayed result

Percent configuration

1. Press SHIFT and then MATH to display the math menu.
2. Press the RANGE ▲ or ▼ key to display "PERCENT", and press ENTER to display the present reference value:

   REF +1.000000 ▲ (factory default)

3. Key in the reference value. The ◀ and ▶ keys control cursor position, and the ▲ and ▼ keys increment/decrement the digit value. To change range, place the cursor on the multiplier and use the ▲ and ▼ keys (m = ×0.001, ▲ = ×1, K = ×1000, and M = ×1,000,000). With the cursor on the polarity sign, the ▲ and ▼ keys toggle polarity.
4. Press ENTER. The MATH annunciator will turn on, and the result of the calculation will be displayed. Note that the calculation will be applied to all measurement functions.
5. To disable mX+b, again press SHIFT and then mX+b. The MATH annunciator will turn off.

NOTES *The result of the percent calculation is positive when the input exceeds the reference and negative when the input is less than the reference.*

The result of the percent calculation may be displayed in exponential notation. For example, a displayed reading of +2.500E+03% is equivalent to 2500% (2.5K%).

Basic operation

NOTE *If using switching module inputs, make sure the front panel INPUTS switch is set to the REAR position (in). If using the front panel inputs, the switch must be in the FRONT position (out).*

1. Configure and enable the mX+b or percent math function as previously explained.
2. Select the desired measurement function.
3. Apply the signal to be measured to a switching channel input or to the front panel inputs.

NOTE *For the Model 7700 switching module, channels 21 and 22 are available for DCI and ACI. Channels 1 through 20 are available for all other functions.*

4. If using a switching module (REAR inputs selected), use the ◀ or ▶ key to select (close) the input channel. If using the front panel inputs (FRONT inputs selected), it does not matter if a switching channel is closed. The result of the math calculation will be displayed.

Scanning

When a simple scan is configured, the present math calculation will apply to all channels in the scan. When an advanced scan is configured, each channel can have its own unique math setup. Details to configure and run a scan are provided in Section 6.

For remote programming, the <clist> parameter is used to configure channels for a scan.

Remote programming — math

Math commands

The commands to perform math calculations are listed in Table 4-2. Details on these commands follow the table.

NOTE *Queries are not included in Table 4-2. All the math commands are provided in Table 14-1.*

Table 4-2
Math commands

Commands[1]	Description	Def
:CALCulate[1]:FORMat <name> [, <clist>]	Select calculation; <name> = NONE, MXB or PERCent.	PERC
:CALCulate[1]:KMATh:MMFactor <NRf> [, <clist>]	Set mX+b "m" factor; <NRf> = -100e6 to 100e6.	1
:CALCulate[1]:KMATh:MBFactor <NRf> [, <clist>]	Set mX+b "b" factor; <NRf> = -100e6 to 100e6.	0
:CALCulate[1]:KMATh:MUNits <char> [, <clist>]	Set mX+b units; see "Setting units."	'X'
:CALCulate[1]:KMATh:PERCent <NRf> [, <clist>]	Set reference value for percent; <NRf> = -4294967295 to +4294967295.	1
:CALCulate[1]:KMATh:PERCent:ACQuire	Use input signal as reference value.	
:CALCulate[1]:STATe <b> [, <clist>]	Enable or disable calculation; <b> = ON or OFF.	(Note 2)
:CALCulate[1]:DATA?	Read result of calculation.	
Channel list parameter: <clist> = (@SCH) where: S = Mainframe slot number (1 or 2) CH = Switching module channel number (must be 2 digits) Examples: (@101) = Slot 1, Channel 1 (@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3 (@101:110) = Slot 1, Channels 1 through 10		

1. The <clist> parameter is used to configure one or more channels for a scan.
2. *RST default is ON, :SYSTem:PRESet is OFF.

mX+b units

The <char> parameter for :CALCulate:KMATh:MUNits must be one character enclosed in single or double quotes. It can be any letter of the alphabet (upper or lower case), the degrees symbol (°) or the ohms symbol (Ω).

The ohms symbol (Ω) and the degrees symbol (°) are not ASCII characters and therefore, must be substituted with the '[' and '\' characters as follows:

:CALCulate:KMAth:MUNits '['	Use ohms symbol (Ω) as units designator.
:CALCulate:KMAth:MUNits '\'	Use degrees symbol (°) as units designator.

Percent reference

The :PERCent <NRf> command specifies the reference value for the percent calculation, while the :PERCent:ACQuire command uses the input signal as the reference value.

The :ACQuire command is only functional if a reading is available. If the instrument is overflowed ("OVERFLOW"), or a reading has not been triggered ("------"), an execution error (-200) occurs when :ACQuire is sent.

The :PERCent <NRf> command is coupled to the :PERCent:ACQuire command. When a reference value is set using :PERCent <NRf>, the :PERCent? query command returns the programmed value. When reference is set using :ACQuire, the :PERCent? query command returns the acquired reference value.

Reading math result

After sending :CALCulate:DATA?, and addressing the Model 2700 to talk, result of the enabled calculation will be sent to the computer. If math is disabled (:CALCulate:FORMat NONE or :CALCulate:STATe OFF), the "raw" reading will be read.

Math programming examples

Example #1 — The following command sequence performs the mX+b calculation for channels 101 and 102 of the Model 7700. Keep in mind that after :CALC:DATA? is sent, the Model 2700 has to be addressed to talk to send the math result to the computer.

```
CALC:FORM MXB                          ' Select mX+b calculation.
CALC:KMAT:MMF 2                        ' Set 'm' factor to 2.
CALC:KMAT:MBF 100                      ' Set 'b' factor to 100.
CALC:STAT ON                           ' Enable math calculation.
ROUT:CLOS (@101)                       ' Close channel 101.
CALC:DATA?                             ' Read mX+b result for channel 101.
ROUT:CLOS (@102)                       ' Close channel 102.
CALC:DATA?                             ' Read mX+b result for channel 102.
```

Example #2 — The following command sequence configures channels 101 through 110 of the Model 7700 to perform the percent calculation when they are scanned.

```
CALC:FORM PERC,(@101:110)              ' Select percent calculation.
CALC:KMAT:PERC 100,(@101:110)          ' Set reference to 100.
CALC:STAT ON,(@101:110)                ' Enable math calculation.
```

NOTE *When channel average is enabled for thermocouple TEMP measurements, the open thermocouple detector cannot be enabled. If it was enabled before channel average was enabled, it will disable. The open thermocouple detector is covered in Section 2.*

Ratio and channel average

With a switching module installed in the Model 2700, the ratio or average of two channels can be calculated and displayed. The ratio calculation can be done on the DCV function, and the channel average calculation can be done on the DCV and TEMP (thermocouples only) functions.

Ratio and channel average are calculated as follows:

$$\text{Ratio} = \frac{\text{Chan A}}{\text{Chan B}}$$

$$\text{Channel Average} = \frac{\text{Chan A} + \text{Chan B}}{2}$$

where; Chan A is the selected (closed) channel.
Chan B is the paired channel for the installed switching module.
Ratio and Channel Average is the displayed result of the respective calculation.

Paired channels are used for ratio and channel average. For example, the Model 7700 switching module has 20 channels that can use ratio and channel average. The primary channels (1 through 10) are linked to the paired channels (11 through 20). Channel 1 is paired to channel 11, channel 2 is paired to channel 12, and so on.

When ratio or channel average is enabled, the Model 2700 measures the closed primary channel. It then opens the primary channel and closes and measures the paired channel. Ratio or channel average is then calculated from the two readings and displayed. If the Model 2700 is configured for continuous measurements, the two-channel scan will continue to repeat and refresh the display with each new calculated reading.

The ratio or channel average calculation can only be enabled if a valid switching channel is closed. If no channel is closed when you attempt to enable one of these calculations, the message "CLOSE A CHAN" message will be displayed to remind you to first close a valid channel.

A primary channel must be closed before you can enable ratio or channel average. If a paired channel is instead closed, message "INVALID CHAN" will be displayed to indicate the settings conflict.

Basic operation

NOTE Make sure the INPUTS switch is set to the REAR position (in).

1. Select and configure (range, filter, rel, etc.) a valid measurement function. For ratio, the only valid function is DCV. For channel average, the only valid functions are DCV and TEMP (TCs only).
2. Use the ◀ or ▶ key to select (close) a primary channel (101 through 110 for the Model 7700). The CLOSE key can also be used.
3. Apply one signal to the selected primary channel, and apply the other signal to the paired channel. For the Model 7700, if the closed primary channel is 101, the paired channel is 111.
4. Enable Ratio or Channel Average:
   a. Ratio — Press SHIFT and then RATIO. The RATIO annunciator will turn on to indicate that the displayed readings are the result of the ratio calculation.
   b. Channel Average — Press SHIFT and then CH-AVG. The DELTA annunciator will turn on to indicate that the displayed readings are the result of the channel average calculation. To disable channel average, again press SHIFT and then CH-AVG.
5. When finished, there are two ways to disable the calculation:
   - Press the OPEN key. The calculation will disable and the channel will open.
   - Press SHIFT and then RATIO to disable ratio, or press SHIFT and then CH AVG to disable channel average. The calculation will disable, but the channel will remain closed.

NOTES The paired channel number is not displayed when it is measured. Only the primary channel is displayed during the 2-channel scan for the calculation.

Enabling ratio disables channel average and conversely, enabling channel average disables ratio.

If either of the channel readings over range ("OVRFLW"), the result of the calculation will also be "OVRFLW."

When using limits with ratio or channel average, the limit values will be compared to the result of the calculation and not to the individual channels.

Scanning

Ratio and channel average can be used in an advanced scan. The 2-channel scan for the calculation is performed for every primary channel that is scanned. For example, assume the Model 7700 is installed in slot 1 and is configured to perform the ratio calculation for 10 channels. When channel 101 is scanned, measurements are performed on channels 101 and on its paired channel (111). The calculation is performed and the result is displayed. When the next channel (102) is scanned, measurements are performed on that channel (102) and on its paired channel (112). The calculation is performed and the result is displayed. This process continues for each scanned channel.

When an advanced scan is configured, each channel can have its own unique setup. That is, one or more channels can use ratio, and other channel(s) can use channel average. Details to configure and run a scan are provided in Section 6.

Advanced scan configuration notes:

1. When a calculation (ratio or channel average) is enabled for a primary scan channel, the following setup actions occur:
   a. The calculation enables for the paired channel.
   b. The primary channel setup (function, range, rel, etc.) will be copied to the paired channel.
2. The filter setup for both scan channels are controlled by the primary channel.
3. After the calculation is enabled, the range setting can be independently set for both the primary and paired channel.
4. Before the calculation is enabled, rel can be independently set for both the primary and paired channel. In general, set up rel from the normal measurement state, then go into the advanced menu and enable rel for the primary and/or paired channel. Details on setting rel for scan channels are provided in Section 4.
5. Settings such as NPLC, aperture, bandwidth, OCOMP, etc., are ignored on the paired channel. These settings are controlled by the primary channel.
6. For remote programming, the <clist> parameter is used to configure channels for a scan (see Table 4-3).

Remote programming — ratio and channel average

Ratio and channel average commands

The ratio and channel average are listed in Table 4-3. Details on these commands follow the table.

NOTE *Queries are not included in Table 4-3. All the math commands are provided in Table 14-1.*

Table 4-3
Ratio and channel average commands

Commands*	Description	Def
[:SENSe[1]]	Optional root command.	
:RATio <b> [, <clist>]	Enable/disable ratio; <b> = ON or OFF.	OFF
:RATio:DELay <NRf> [, <clist>]	Set delay (in secs); <NRf> = 0 to 999999.999.	0.5
:CAVerage <b> [, <clist>]	Enable/disable channel average; <b> = ON or OFF.	OFF
:CAVerage:DELay <NRf> [, <clist>]	Set delay (in secs); <NRf> = 0 to 999999.999.	0.5
Channel list parameter: <clist> = (@SCH) where: S = Mainframe slot number (1 or 2) CH = Switching module channel number (must be 2 digits) Examples: (@101) = Slot 1, Channel 1 (@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3 (@101:110) = Slot 1, Channels 1 through 10		

*The <clist> parameter is used to configure one or more channels for a scan.

Enabling/disabling ratio or channel average

As with front panel operation, enabling ratio disables channel average and conversely, enabling channel average disables ratio.

Ratio and channel average delay

:RATio:DELay or :CAVerage:DELay sets the delay between the two channel measurements for the enabled calculation. This delay is applied after the trigger delay in the trigger model (see Section 7 for details). This delay cannot be set from the front panel. The 0.5s default delay keeps the relays from cycling too fast. Setting a shorter delay may shorten the life of the relays.

It does not matter which of the two commands you use to set the delay. The set delay affects both ratio and channel average.

Ratio and channel average programming examples

Example #1 — The following command sequence performs the ratio calculation using primary channel 102 of the Model 7700. After READ? is sent, the Model 2700 must be addressed to talk to return the result of the calculation.

```
*RST                                    ' One-shot measure mode.
FUNC 'VOLT'                             ' Select DCV function.
ROUT:CLOS (@102)                        ' Close channel 102.
RAT ON                                  ' Enable the ratio calculation.
READ?                                   ' Read the result of the calculation.
```

Example #2 — The following command sequence configures channels 103 and 105 for the ratio and channel average calculations. When channel 103 is scanned, the ratio calculation is based on DCV measurements of channels 103 and 113. When channel 105 is scanned, the channel average calculation is based on TEMP measurements of channels 105 and 115.

```
FUNC 'VOLT',(@103)                    ' Set 103 for DCV.
RAT ON,(@103)                         ' Set 103 for ratio on.
FUNC 'TEMP',(@105)                    ' Set 105 for TEMP.
CAV ON,(@105)                         ' Set 105 for channel average on.
```

dB

Expressing DC or AC voltage in dB makes it possible to compress a large range of measurements into a much smaller scope. The relationship between dB and voltage is defined by the following equation:

$$dB = 20\log \frac{V_{IN}}{V_{REF}}$$

where: V_{IN} is the DC or AC input signal.
V_{REF} is the specified voltage reference level.

The instrument will read 0dB when the reference voltage level is applied to the input.

If a relative value is in effect when dB is selected, the value is converted to dB then REL is applied to dB. If REL is applied after dB has been selected, dB has REL applied to it.

NOTES *The dB calculation takes the absolute value of the ratio V_{IN} / V_{REF}*

The largest negative value of dB is -160dB. This will accommodate a ratio of $V_{IN} = 1\mu V$ and $V_{REF} = 1000V$.

dB configuration

Remote programming must be used to configure the Model 2700 for dB measurements. It cannot be configured from the front panel.

Scanning

Typically a scan using dB is configured and run using remote programming. However, once dB is selected using remote programming, a simple dB scan can be configured and run from the front panel. When the simple scan is configured, it will use the dB measurement setup for each channel in the scan. Details on configuring and running a scan are provided in Section 6.

NOTE *See Section 6 to configure and run a scan.*

Remote programming — dB

dB commands

The dB commands are listed in Table 4-4. Details on these commands follow the table.

NOTE *Queries are not included in Table 4-4. All the dB commands are provided in Table 14-10.*

Table 4-4
dB commands

Commands*	Description	Def
DCV dB commands:		
:UNITs:VOLTage[:DC] <name> [, <clist>]	Select DCV measurements; <name> = V or DB.	V
:UNITs:VOLTage[:DC]:DB:REFerence <n> [, <clist>]	Set reference in volts; <n> = 0 to 1000.	1
ACV dB commands:		
:UNITs:VOLTage:AC <name> [, <clist>]	Select ACV measurements; <name> = V or DB.	V
:UNITs:VOLTage:AC:DB:REFerence <n> [, <clist>]	Set reference in volts; <n> = 0 to 1000.	1
Channel list parameter: <clist> = (@SCH) where: S = Mainframe slot number (1 or 2) CH = Switching module channel number (must be 2 digits) Examples: (@101) = Slot 1, Channel 1 (@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3 (@101:110) = Slot 1, Channels 1 through 10		

* The <clist> parameter is used to configure one or more channels for a scan. Each channel in the <clist> must be set to the function specified by the rel (reference) command. If not, a conflict error (-221) will occur. For example, :UNITs:VOLTage:AC dB, (@101) is only valid if scan channel 101 is set for the ACV function.

Programming examples — dB

Example #1 — The following command sequence configures the Model 2700 to perform DCV dB measurements. A 1V input will be measured as 0dB.

```
FUNC 'VOLT'                          ' Select DCV function.
UNIT:VOLT DB                         ' Select DCV dB.
UNIT:VOLT:DB:REF 1V                  ' Set dB reference to 1V.
```

Example #2 — The following command sequence configures channels 101 and 105 of the Model 7700 to perform ACV dB measurements when they are scanned. A 10V input will be measured as 0dB.

```
FUNC 'VOLT:AC',(@101,105)            ' Set 101 and 105 for ACV.
UNIT:VOLT:AC DB,(@101,105)           ' Set 101 and 105 for dB.
UNIT:VOLT:AC:DB:REF 1V,(@101,105)    ' Set 101 and 105 for 10VAC dB
                                     ' reference.
```

5 Buffer

- **Buffer overview** — Summarizes basic buffer (data store) capabilities.
- **Front panel buffer** — Explains how to store and recall readings, and discusses the various statistics available on buffer data including minimum and maximum values, average (mean), standard deviation, and peak-to-peak values.
- **Remote programming** — Summarizes the commands to control the data store and provides a programming example.

Buffer overview

The Model 2700 has a data store (buffer) to store from 2 to 55,000 readings. The instrument stores the readings that are displayed during the storage process. Each timestamped reading includes the buffer location number and a timestamp.

The data store also provides statistical data on the measured readings stored in the buffer. These include minimum, maximum, average, peak-to-peak, and standard deviation.

NOTE *When scanning, the readings are automatically stored in the buffer.*

Front panel buffer

Auto clear

With buffer auto clear enabled, the buffer is cleared (readings lost) before a new storage operation starts. The buffer can be manually cleared by setting the number of readings to store (buffer size) to 00000.

When buffer auto clear is disabled, the buffer is not cleared and the buffer size is set to 55,000. Each subsequent storage operation appends the readings to the buffer. When the buffer fills with 55,000 readings, the storage process stops. The 55,0000 readings are cleared before the next storage operation starts.

With buffer auto clear disabled, the only two valid buffer size values are 55000 and 00000. Buffer size 00000 clears the buffer. Entering any other buffer size value resets the buffer size to 55000.

NOTES *If the buffer is empty when the Model 2700 is turned off, buffer auto clear will enable (Y) when it is turned back on.*

*The auto clear setting (on or off) is not affected by any of the reset operations: factory (FACT), *RST (front panel and remote operation), or SYSTem:PRESet defaults. If the buffer is not empty, the instrument will power up to the last auto clear setting. Keep in mind that if the instrument powers up with auto-clear off, buffer size is fixed at 55000. You will have to disable auto clear to change the buffer size.*

Enabling/disabling buffer auto clear

1. Press SHIFT and then SETUP.
2. Use the ▲ and ▼ keys to display the present state of buffer auto clear (BUF AUTOCLR); Y (yes) or N (no). To retain the present state of buffer auto clear, press ENTER or EXIT.

NOTE *If you change the state of buffer auto clear, the buffer will clear.*

3. To change the state of buffer auto clear, press ▶ to place the cursor on the present setting (Y or N).
4. Use thee ▲ or ▼ key to display the desired setting (Y=enabled, N=disabled), and press ENTER.

NOTE *For remote programming, the TRACe:CLEar and TRACe:CLEar:AUTO commands are used to clear the buffer (see Table 5-1).*

Timestamps

Each stored reading is referenced to either a real-time clock timestamp or to a relative timestamp.

Relative timestamp — With relative selected, there are two timestamp types for each reading; absolute and delta. The absolute timestamp (S) references each stored reading to zero seconds. Therefore, the first reading in the buffer has an absolute timestamp of zero seconds. The delta timestamp (dS) indicates the time (in seconds) between the displayed reading and the reading before it. The resolution for each timestamp is 0.001 sec.

NOTE *With auto clear disabled and the relative timestamp selected, every stored reading is referenced to the first reading (#0), even if the buffer is stopped and started again. For example, assume you stored 10 readings in the buffer, and one hour later, you store 10 more readings. The timestamps for all 20 readings are referenced to the first reading. Therefore, the timestamp for the 11th reading (#10) is one hour (360 seconds).*

When the Model 2700 is turned off, the relative timestamp resets to 0sec when the instrument is turned back on. If you have readings stored in the buffer and auto clear is disabled when the unit is turned off, subsequent stored readings will be appended to the "old" group of readings. However, the relative timestamps for the "new" readings will be referenced to 0sec.

NOTE *When recalling stored readings from the front panel, both absolute and delta timestamps are provided. For remote operation, the absolute or delta timestamp is returned with each buffer reading. The TRACe:TSTamp:FORMat command selects the relative timestamp type (see Table 5-1).*

Real-time clock timestamp — With the real-time clock selected, each stored reading is timestamped with the time and date. For the time, the seconds reading has 0.01 sec resolution.

Configuring timestamp

Setting time and date

For the real-time clock, the time and date is set at the factory. However, you can check and correct the time and date as follows:

Perform the following steps to set the time:

1. Press SHIFT and then SETUP.
2. Use the ▲ and ▼ keys to display "SET TIME" and press ENTER. The displayed clock will be running in the hour:minute:second AM/PM format.
3. Use the edit keys (◀, ▶, ▲, and ▼) to set the hour, minute, and AM/PM (seconds cannot be set), and press ENTER.

Perform the following steps to set the date:

1. Press SHIFT and then SETUP.
2. Use the ▲ and ▼ keys to display "SET DATE" and press ENTER to display the date in the month/day/year format.
3. Use the edit keys (◀, ▶, ▲, and ▼) to set the date (month/day/year), and press ENTER.

Selecting timestamp

Perform the following steps to select either the real-time clock timestamp or the relative timestamp:

NOTE *If there are readings stored in the buffer, they will be lost (cleared) if you change the timestamp setting. The message "BUF CLEARED" will be displayed to indicate the buffer readings were lost.*

1. Press SHIFT and then SETUP.
2. Use the ▲ and ▼ keys to display "TSTAMP."
3. Press the ▶ key to place the cursor on the presently selected timestamp; REL or RTCL.
4. Use the ▲ or ▼ key to display the relative (REL) or real-time clock (RTCL), and press ENTER.

Storing readings

Perform the following steps to store readings:

1. Set up the Model 2700 for the desired configuration.
2. Press the STORE key.
3. Use the ◀, ▶, ▲, and ▼ keys to specify the number of readings to store in the buffer (2 to 55000). Pressing the AUTO key sets the readings count to 00000.

NOTE *With buffer auto clear disabled, the only valid buffer size values are 55000 and 00000 (which clears the buffer). Any other buffer size value is ignored.*

4. Press ENTER. The asterisk (*) annunciator turns on to indicate the buffer is enabled. It will turn off when the storage is finished.
5. The buffer can be stopped at any time by pressing EXIT.

NOTE *Stored readings are not lost when the instrument is turned off. To clear the buffer, set the reading value to "00000" and press ENTER.*

NOTE *For remote programming, the continuous storage mode can be selected. After the buffer fills, operation wraps around to the beginning of the buffer (location #0) and starts to overwrite old reading data (see TRACe:FEED:CONTrol command in Table 5-1).*

Recalling readings

Readings stored in the buffer are displayed by pressing the RECALL key. The readings are positioned at the left side of the display, while the buffer location number (reading number) and timestamps are positioned at the right side.

Perform the following steps to view stored readings and buffer statistics:

1. Press RECALL. The "BUFFER" annunciator indicates that stored readings are being displayed. The double-arrow annunciator indicates that more data can be viewed with the ◀, ▶, ▲, and ▼ keys.
2. As shown in Figure 5-1 and Figure 5-2, use the ◀, ▶, ▲, and ▼ keys to navigate through the reading numbers, reading values, statistics and timestamps. For any of the buffer statistics (standard deviation, average, peak-to-peak, minimum and maximum), the "STAT" annunciator is on.

NOTE *The longer you hold in the ▲ or ▼ key, the faster you will scroll through the buffer. After a while, scrolling speed will increase by incrementing (or decrementing) the buffer reading number by 100, and then finally by 500. When you get close to the desired reading number, release the ▲ or ▼ key. Again press and hold in the ▲ or ▼ key to scroll one reading at a time.*

Figure 5-1
Recalling buffer data — relative timestamp

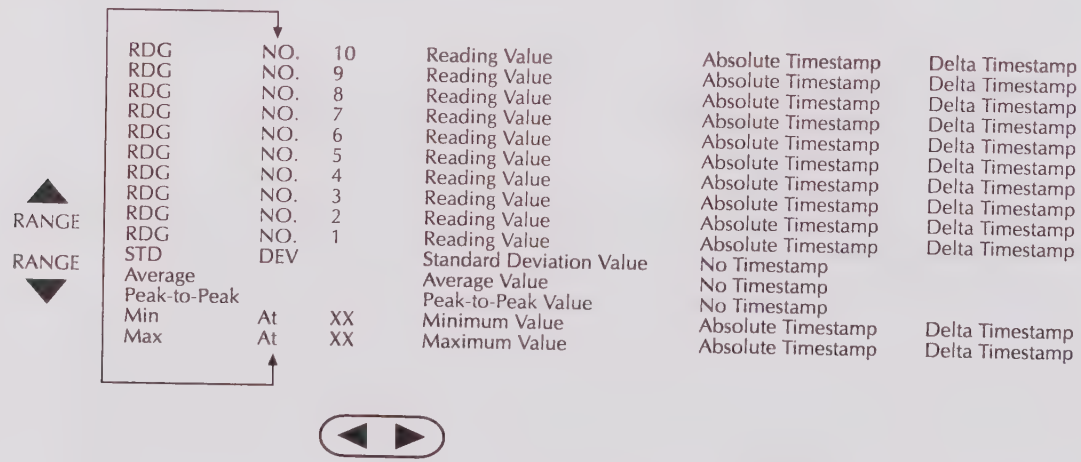
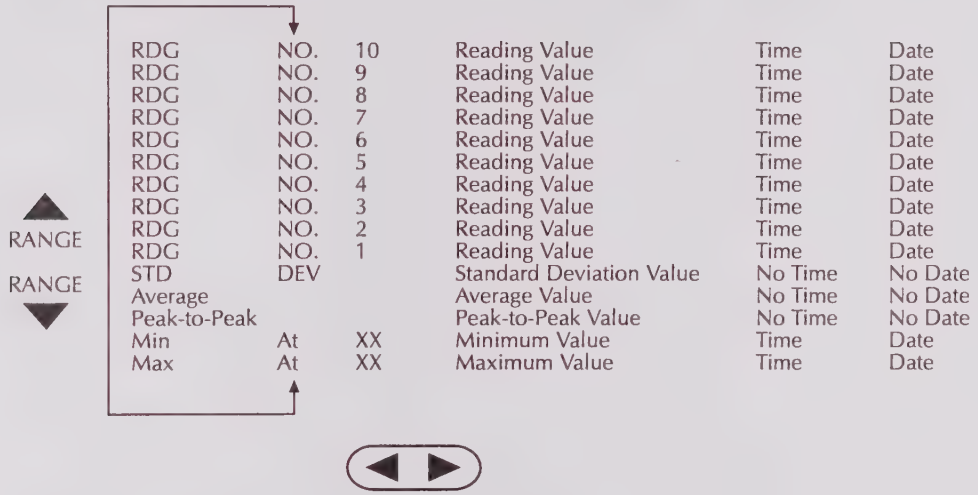

RANGE ▲
RANGE ▼
RDG NO. 10 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 9 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 8 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 7 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 6 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 5 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 4 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 3 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 2 Reading Value Absolute Timestamp Delta Timestamp
RDG NO. 1 Reading Value Absolute Timestamp Delta Timestamp
STD DEV Standard Deviation Value No Timestamp
Average Average Value No Timestamp
Peak-to-Peak Peak-to-Peak Value No Timestamp
Min At XX Minimum Value Absolute Timestamp Delta Timestamp
Max At XX Maximum Value Absolute Timestamp Delta Timestamp
◀ ▶

Figure 5-2
Recalling buffer data — real-time clock timestamp


RANGE
RANGE
RDG NO. 10 Reading Value Time Date
RDG NO. 9 Reading Value Time Date
RDG NO. 8 Reading Value Time Date
RDG NO. 7 Reading Value Time Date
RDG NO. 6 Reading Value Time Date
RDG NO. 5 Reading Value Time Date
RDG NO. 4 Reading Value Time Date
RDG NO. 3 Reading Value Time Date
RDG NO. 2 Reading Value Time Date
RDG NO. 1 Reading Value Time Date
STD DEV Standard Deviation Value No Time No Date
Average Average Value No Time No Date
Peak-to-Peak Peak-to-Peak Value No Time No Date
Min At XX Minimum Value Time Date
Max At XX Maximum Value Time Date

Buffer statistics

Minimum and maximum

This mode displays the minimum and maximum readings stored in the buffer. The buffer location number and timestamp are also provided for these readings.

Peak-to-peak

This mode displays the peak-to-peak reading (peak-to-peak = Maximum - Minimum).

Average

The average mode displays the mean (average) of all measured readings stored in the buffer. The following equation is used to calculate mean:

$$y = \frac{\sum_{i=1}^{n} X_i}{n}$$

where: y is the average.
X_i is a stored reading.
n is the number of stored readings.

Standard deviation

This mode displays the standard deviation of buffered readings. The following equation is used to calculate standard deviation:

$$y = \sqrt{\frac{\sum_{i=n-1}^{n} X_i^2 - \left(\frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)^2\right)}{n-1}}$$

where: y is the standard deviation.
X_i is a stored reading.
n is the number of stored readings.

NOTE *If the standard deviation calculation is being performed on a buffer that has more than 1000 readings, the "CALCULATING" message will flash to indicate that the Model 2700 is busy. While busy with the calculation, front panel keys will not operate.*

Remote programming — buffer

NOTE *You cannot use :READ? to trigger measurements and return readings if the sample count (:SAMPle:COUNt) is >1 and the buffer is not empty. To use :READ? to perform multi-sample measurements, you will have to first clear the buffer using the :TRACe:CLEar command.*

NOTE *The measurement event register can be read to check when the buffer becomes ¼, ½, ¾, or full. Status registers are covered in Section 10.*

Buffer commands

The commands to perform buffer operations are listed in Table 5-1. Details on these commands follow the table.

NOTE *Optional command words and most queries are not included in Table 5-1. The unabridged tables for all SCPI commands are provided in Section 14.*

Table 5-1
Buffer commands

Command	Description	Default[1]	Ref
SYSTem:TIME <hr, min, sec>	Set clock time in 24-hour format.		A
SYSTem:DATE <yr, mo, day>	Set clock date; yr specified as 19xx or 20xx		B
SYSTem:TSTamp:TYPE <name>	Select timestamp; <name> = RELative or RTCLock	REL	C
TRACe:CLEar	Clear the buffer immediately.		D
TRACe:CLEar:AUTO <b>	Enable/disable buffer auto-clear; <b> = ON or OFF.	ON	D
TRACe:FREE?	Query bytes available and bytes in use.		E
TRACe:POINts <NRf>	Specify size of buffer; <NRf> = 2 to 55000.	100	F
TRACe:TSTamp:FORMat <name>	Select timestamp format; <name> = ABSolute or DELTa.	ABS	G
TRACe:FEED <name>	Select source of readings; <name> = SENSe[1], CALCulate[1] or NONE.	CALC	H
TRACe:FEED:CONTrol <name>	Set buffer control; <name> = NEVer, NEXT, or ALWays.	NEV	H
TRACe:DATA?	Read all readings in the buffer.		I
TRACe:DATA:SELected? <start>, <count>	Specify readings to be returned; <start> = starting point, <count> = number of readings.		J
TRACe:NEXT?	Query buffer location of last stored reading.		J
FORMat:ELEMents <item list>	Specify elements for :TRACe:DATA? response message; <item list> = READing, CHANnel, UNITs, RNUMber, and TSTamp.	(Note 2)	K
CALCulate2:FORMat <name>	Select buffer statistic; <name> = MINimum, MAXimum, MEAN, SDEViation, PKPK, or NONE.	NONE	L
CALCulate2:STATe <b>	Enable/disable statistic calculation; <b> = ON or OFF.	OFF	L
CALCulate2:IMMediate	Calculate data in buffer.		L
CALCulate2:IMMediate?	Calculate data and read result.		L
CALCulate2:DATA?	Read the selected buffer statistic.		L

Notes:
1. :SYSTem:PRESet and *RST have no effect on :TRACe commands. The listed defaults for :TRACe commands are set at the factory.
2. The :SYSTem:PRESet and *RST default is READ, UNIT, RNUM, and TST.

A. :SYSTem:TIME <hr, min, sec> **Set clock time**

Use to set the clock time in the 24-hour format (hr/min/sec). Seconds can be set to 0.01 sec resolution. Examples:

```
SYST:TIME 13, 23, 36        'Set time to 1:23:36 PM.
SYST:TIME 3, 25, 28.5       'Set time to 3:25:28.5 AM.
```

The SYSTem:TIME? command can be used to read the time. Note that it returns the actual clock time and not the time parameter specified by the TIME command.

B. :SYSTem:DATE <yr, mo, day> **Set clock date**

Use to set the clock date in the year/month/day format. When setting the year, a 4-digit value must be used. Example:

```
SYSTem:DATE 1999, 11, 10    'Set clock date to November 11, 1999.
```

C. :SYSTem:TSTamp:TYPE RELative | RTClock **Select timestamp**

Use to select the relative timestamp or the real-time clock timestamp. Note that changing the timestamp clears the buffer.

D. :TRACe:CLEar **Clear the buffer**
:TRACe:CLEar:AUTO ON | OFF **Control (on/off) buffer auto-clear**

:TRACe:CLEar — Used to clear the buffer. Buffer readings are not lost (cleared) when the Model 2700 is turned off.

:TRACe:CLEar:AUTO — With auto-clear enabled, the buffer will automatically clear when the storage process starts. When disabled, readings will append to "old" readings in the buffer until the buffer becomes full (55,000 readings) or the storage process is stopped. Disabling auto-clear automatically sets the buffer size to 55,000.

E. :TRACe:FREE? **Query status of storage memory**

Returns two values separated by commas. The first value indicates, in bytes, memory available for storage, while the second value indicates the number of bytes being used for stored readings.

F. :TRACe:POINts 2 to 55000 **Set buffer size**

With buffer auto-clear enabled, you can set the buffer to store from 2 to 55,000 readings. A buffer size of zero or one is not valid (error -222).

With buffer auto-clear disabled, you cannot use this command to set buffer size (error -221) because it is fixed at 55,000.

NOTE *The ¼ full and ¾ buffer full measurement events are not intended to be used with buffer size smaller than four readings. See "Status structure" (Section 10) for details.*

G. :TRACe:TSTamp:FORMat ABSolute | DELta **Select timestamp format**

For front panel operation, both timestamp formats (absolute and delta) can be recalled. For remote programming, you can only use one timestamp at a time.

NOTE Changing the timestamp format clears the buffer.

The timestamp will only be included with a returned buffer reading if it is specified as a data element (see :FORMat:ELEMents).

H. :TRACe:FEED SENSe | CALCulate | NONE **Select source of readings**
:TRACe:FEED:CONTrol NEXT| ALWays | NEVer **Select buffer control**

:TRACe:FEED — The SENSe parameter selects readings before any enabled mX+b or Percent math calculation. For the CALCulate parameter, the result of the calculation is stored in the buffer. The NONE parameter disables storage into the buffer. Math functions are covered in Section 4.

NOTE In order to store readings in the buffer, :TRACe:FEED cannot be set to NONE.

:TRACe:FEED:CONTrol — Selecting NEXT enables the buffer. After the specified number of readings (buffer size) are stored, buffer operation disables. The ALWays parameter places the buffer into a continuous filling mode. After the specified number of readings are stored, operation wraps back to the first buffer location and overwrites the previous readings. The NEVer parameter disables buffer operation.

I. :TRACe:DATA? **Read buffer**

Use TRACE:DATA? to retrieve all readings that are stored in the buffer. You can send this command even if the instrument is still storing readings. When :TRACe:DATA? is sent, it will return the readings stored up to that point in time. Subsequent :TRACe:DATA? commands will not retrieve readings already returned. However, once the buffer has filled and you have retrieved all buffer readings, you can again send :TRACe:DATA? to retrieve all the stored readings.

The data elements returned with each stored reading depends on which ones are selected with :FORMat:ELEMents command (see Section 13 for details).

J. :TRACe:DATA:SELected <start>, <count> **Specify readings to return**
:TRACe:NEXT? **Query location of last buffer reading**

Use the TRACe:DATA:SELected command to specify which stored readings to return. The <start> parameter specifies the first stored reading to return. Note that the first stored reading in the buffer is #0. The <count> parameter specifies the number of readings to return.

When the storage process is aborted, you can use TRACe:NEXT? to determine the buffer location of the last stored reading. For example, if the last reading is stored at memory location #36, TRACe:NEXT? will return the value 36. This query is useful when using the buffer in the continuous storage mode (TRACe:FEED:CONTrol ALWays) as demonstrated by the following example:

Example — Assume the buffer is configured for continuous (wrap-around) storage, and the buffer size is 100. At some point you stop the storage process and want to return all the readings that were stored since the last time the buffer filled. The following command will return the buffer location of the last stored reading:

```
TRACe:NEXT?                    'Query buffer location of last stored reading.
```

Assume that the above query returned value 36. Now you can use that value as the <count> parameter for the following command to return the 37 readings:

```
TRACe:SELected:DATA? 0, 36     'Return buffer readings 0 through 36.
```

K. :FORMat:ELEMents <item list> **Select elements for :TRACe:DATA?**

<item list> = READing, CHANnel, UNITs, RNUMber, TSTamp

The data returned by :TRACe:DATA? can include from one to all five data elements shown in the above item list. For example, if you want the units and reading number included with the reading, you would send this command:

```
:FORMat:ELEMents  READing, UNITs, RNUMber.
```

Only the elements defined by the list are used. Elements not included in the list are not used. You can specify the elements in the list in any order, but they must be separated by commas.

The data elements that can accompany the reading are summarized as follows. More details on data elements are provided in Section 13 (see :FORMat subsystem).

- CHANnel — References the reading to a switching module channel. If the reading is not for a switching module, channel 000 will be returned.
- UNITs — Identifies the measurement function (i.e., VDC).
- RNUMber — References the reading to the buffer reading number.
- TSTamp — Timestamps the reading (ABSolute or DELTa timestamp as set by the :TRACe:TSTamp:FORMat command).

L. **:CALCulate2:FORMat** <name> — **Select buffer statistic**
:CALCulate2:STATe ON | OFF — **Control (on/off) buffer statistic**
:CALCulate2:IMMediate — **Calculate data in buffer**
:CALCulate2:IMMediate? — **Calculate and read result**
:CALCulate2:DATA? — **Read result of statistic calculation**

<name> = MINimum | MAXimum | MEAN | SDEViation | PKPK | NONE

After the selected buffer statistic is enabled, :IMMediate or :IMMediate? must be sent to calculate the statistic from the data in the buffer. The :CALCulate2:DATA? command does not initiate a calculate operation. It simply returns the result of the last calculation. If new data is stored in the buffer, you must again send :IMMediate or :IMMediate? to recalculate the statistic from that new data.

NOTE *If the standard deviation calculation is being performed on a buffer that has more than 1000 readings, the "CALCULATING" message will flash to indicate that the Model 2700 is busy. While busy with the calculation, remote programming commands will not execute. When writing a test program, make sure to include a delay for this busy period to avoid a bus time-out.*

Programming example

The following command sequence stores 20 readings in the buffer and then calculates the mean for those readings. Note that after sending a query command, the Model 2700 must be addressed to talk.

```
' Store readings:
TRAC:CLE:AUTO ON                ' Enable buffer auto-clear.
TRAC:POIN 20                    ' Set buffer size to 20.
TRAC:FEED SENS                  ' Select raw readings for storage.
TRAC:FEED:CONT NEXT             ' Start storage process.
TRAC:DATA?                      ' Request all stored readings.

' Calculate mean:
CALC2:FORM MEAN                 ' Select mean calculation.
CALC2:STAT ON                   ' Enable mean calculation.
CALC2:IMM?                      ' Perform calculation and request result.
```

6
Scanning

- **Scanning fundamentals** — Explains channel assignments (slot/channel programming format) and the basic scan process. Block diagrams (known as trigger models) are provided to help explain the STEP and SCAN operations.
- **Scan configuration** — Provides the step-by-step procedures to configure a simple scan or an advanced scan. Covers other scan options, including delay, monitor, auto configuration, saving setups, and auto scan.
- **Scan operation** — Provides the step-by step procedures to perform a basic scan, a manual/external trigger scan, and a monitor scan.
- **Remote programming - scanning** — Provides the commands used for scan operation and includes a simple scanning programming example. Also summarizes various aspects of remote scan operation.
- **Scanning examples** — Provides a couple of typical scan operation examples (front panel and remote programming).

Scanning fundamentals

The Model 2700 can scan the channels of one or two installed Keithley switching modules. Each scan channel can have its own unique setup. Aspects of operation that can be uniquely set for each channel include function, range, rate, AC bandwidth, rel, filter, digits, math, Ω offset compensation, TEMP transducers, limits, channel average, channel ratio, and volts dB.

NOTE *Readings for scanned channels are automatically stored in the buffer. With buffer auto clear enabled (which is the default), the buffer clears when the scan is started. When disabled, scan readings are appended to the buffer. The :TRACe:CLEar:AUTO <b> command is used to enable/disable buffer auto clear (see Section 5).*

NOTE *A pseudocard can be "installed" in an empty slot. With the 7700 pseudocard installed, the instrument will operate as if a Model 7700 switching module is installed in the slot. This allows the user to configure a scan and exercise its operation before the switching module is installed in the Model 2700. Use the following commands to "install" 7700 pseudocards in empty slots:*

```
:SYSTem:PCARd1 C7700      'Install' 7700 pseudocard in slot 1.
:SYSTem:PCARd2 C7700      'Install' 7700 pseudocard in slot 2.
```

Pseudocards for other switching modules can instead be "installed." Details on all pseudocards are provided in Section 1.

There are SCPI commands to query the capabilities of the installed switching modules. For example, the following queries are provided to determine which channels are available for volts/2-wire ohms, and which channels are available for amps. Note that the returned values for the Model 7700 switching module are shown in parenthesis.

```
:SYSTem:CARDx:VCHannel[:STARt]?    ' Query first volt/Ω2 channel (7700; "1").
:SYSTem:CARDx:VCHannel:END?        ' Query last volt/Ω2 channel (7700; "20").

:SYSTem:CARDx:ACHannel[:STARt]?    ' Query first amps channel (7700; "21").
:SYSTem:CARDx:ACHannel:END?        ' Query last amps channel (7700; "22").
```

where; CARDx = CARD1 (for module in slot 1)
= CARD2 (for module in slot 2)

All the commands to query switching module capabilities are covered in Table 14-7.

Channel assignments

A switching module has a certain number of channels. For example, the Model 7700 switching module has 22 channels (1 through 22). When you encounter a 1 or 2-digit channel number in this manual, the switching module channel is the point of discussion.

A switching module can be installed in one of two slots of the mainframe. Therefore, to close/open or scan a channel, it is necessary to specify the slot location and channel number of the switching module. This is accomplished by using a 3-digit channel number for the mainframe. The first digit (1 or 2) indicates the slot number, and the next two digits indicate the channel number of the switching module. Examples:

Channel 101	Slot 1, channel 1
Channel 112	Slot 1, channel 12
Channel 220	Slot 2, channel 20

Scan process

Basic scan — For functions that use 2-wire measurements, the basic scan process is to (1) open any closed channel, (2) close a channel, and then (3) perform the measurement. This 3-step process is repeated for each channel in the scan. The last scanned channel opens.

Channel pair scan — For the functions that use 4-wire measurements (Ω4 and 4-wire RTD TEMP), the scan process uses paired channels. The scan process is to (1) open any closed channels, (2) close the paired channels, and then (3) perform the 4-wire measurement. The last scanned channel pair opens.

NOTE *For the Model 7700 switching module, primary channels 1 through 10 are paired to channels 11 through 20. Channel 1 is paired to channel 11, channel 2 is paired to channel 12, channel 3 is paired to channel 13, and so on.*

Calculations using channel pairs — Ratio and channel average performs measurements on two channels and then calculates (and displays) the result. Therefore, these 2-channel calculations also use paired channels. The scan process is to (1) open any closed channels, (2) close the primary (displayed) channel and perform a measurement, (3) open the primary channel, (4) close the paired channel and perform a measurement, (5) calculate and display the result, and finally (6) open the paired channel.

NOTE *When scanning, the displayed channel number (i.e., 101) is not necessarily the channel that is presently closed:*

If both a reading AND a scan channel are displayed, the reading and annunciators pertain to that channel, but that channel is no longer closed. The next channel in the scan list is the one that is now closed. Therefore, the reading (and annunciators) pertain to the channel and does not necessarily indicate the present state of the Model 2700.

If the display is blanked (-------), the displayed channel is closed and has not been measured.

Trigger models

NOTE *The following information on trigger model operations apply specifically to front panel operation.*

Block diagrams, known as trigger models, are used to show the two fundamental scan operations; STEP or SCAN. These two scan operations are enabled by the STEP and SCAN keys respectively. The trigger models for scanning are shown in Figure 6-1 and Figure 6-2.

NOTES *The trigger model in Figure 6-2 also applies for bus operation. See "Remote programming - scanning" for differences between front panel SCAN and remote scanning.*

For the following discussion, refer to Figure 6-1 for STEP operation, and Figure 6-2 for SCAN operation.

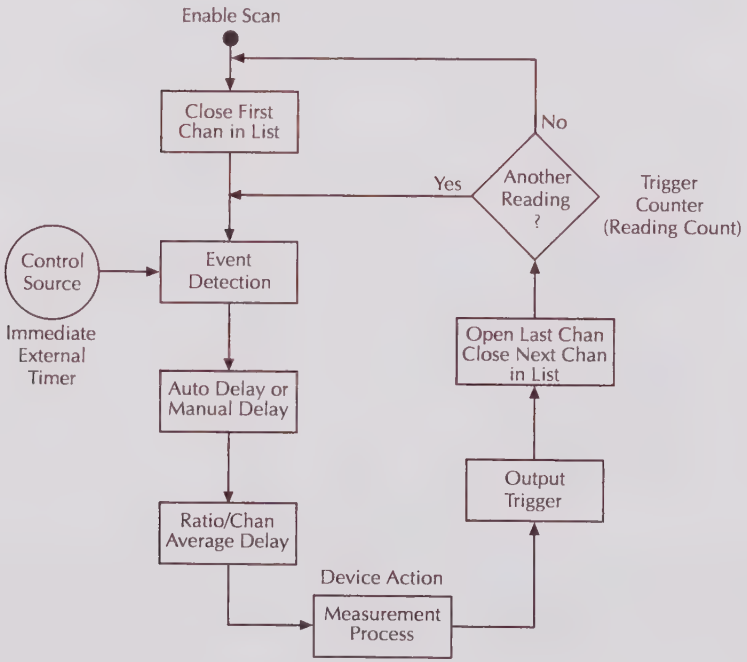
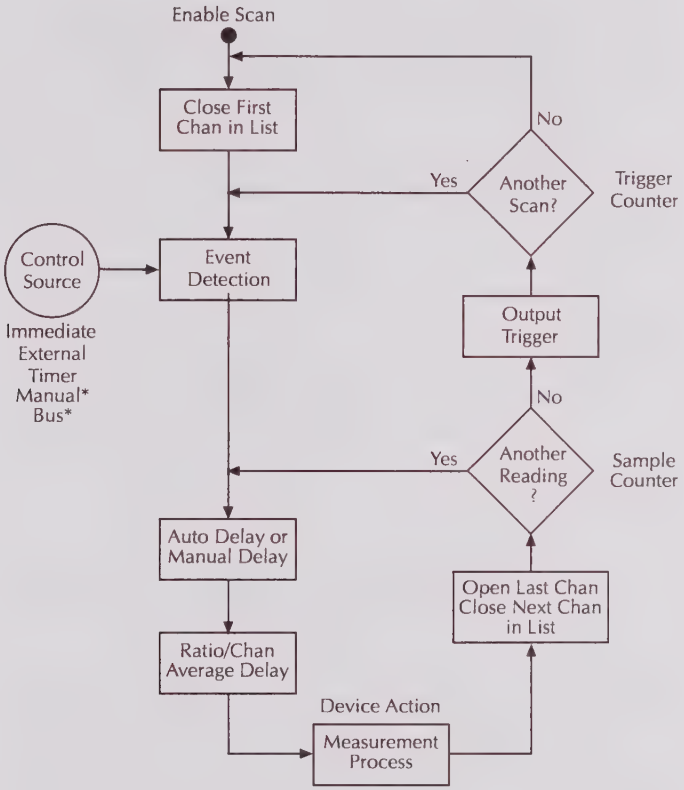


Figure 6-1
Trigger model with STEP function

Figure 6-2
Trigger model with SCAN function



*Remote programming only

STEP operation overview — When the STEP key is pressed, the Model 2700 leaves the idle state, closes the first channel and waits for the programmed trigger event. After the trigger is detected, the instrument may be subjected to one or more delays before performing the measurement.

After a reading is taken and stored in the buffer, the Model 2700 outputs a trigger pulse, opens the closed channel, and then closes the next channel in the scan list. The instrument then waits for another trigger event to measure the channel. After the last channel is scanned, the instrument returns to the idle state with the first channel in the scan list closed.

SCAN operation overview — When the SCAN key is pressed, the Model 2700 leaves the idle state, closes the first channel and waits for the programmed trigger event. After the trigger is detected, the instrument may be subjected to one or more delays before performing the measurement.

After a reading is taken and stored in the buffer, the Model 2700 opens the closed channel, and then closes the next channel in the scan list. Operation keeps looping around to measure all channels in the scan list. After the last channel in the scan list is measured, the Model 2700 outputs a trigger pulse.

If programmed to again scan the channels in the scan list, the Model 2700 will wait at the control source for another trigger event. After all the scan list channels are again measured, the Model 2700 will output another trigger pulse. After all programmed scans are completed, the instrument returns to the idle state with the first channel in the scan list closed.

The individual components of the trigger models are explained as follows:

Idle

When a scan is enabled (STEP or SCAN annunciator on), operation goes into the idle state and immediately drops down to the control source. Note that after the last channel in the scan is measured, operation returns to the idle state, where measurements are halted and the first channel in the list is closed.

Control sources

For front panel operation, there are three control sources to manage the scan; Immediate, Timer and External Trigger. Operation is held up at the selected control source until the appropriate trigger event is detected.

STEP operation — When the trigger event is detected, a channel is measured. The scan pointer then loops back to the control source and waits for the next trigger event to occur.

SCAN operation — When the trigger event is detected, all the channels in the scan list are scanned. The scan pointer then returns to the control source and waits for the next trigger event to be detected.

Immediate control source

With immediate triggering, event detection is immediate allowing channels to be scanned.

Timer control source

When the scan process starts, the timer starts, and event detection is satisfied immediately on the initial pass through the trigger model. Each subsequent detection is satisfied when the user-set timer interval elapses. If the timer interval has already elapsed by the time the scan pointer has returned to the control source, event detection is satisfied and operation continues immediately.

External trigger control source

Pressing the EX TRIG key places the instrument in the external trigger mode (TRIG annunciator on). When the STEP or SCAN key is then pressed, that scan is enabled. However, the scan does not start until an external trigger is received or the TRIG key is pressed. The external trigger or TRIG keypress satisfies event detection.

STEP operation — Each time an external trigger is received (or TRIG key is pressed), one channel is scanned.

SCAN operation — Each time an external trigger is received (or TRIG key is pressed), one complete scan is performed.

Delays

As shown in the trigger models, operation may be subjected to one or more delays before a channel is measured.

Auto Delay or Manual Delay — The user can select either auto delay or manual delay. With auto delay selected, the instrument automatically selects a delay period that will provide sufficient settling for function and autorange changes, and multi-phase measurements.

The auto delay period cannot be adjusted by the user. It is a fixed delay for the selected function and range (see Table 7-1 in Section 7).

NOTE *When scanning, the auto delay times in Table 7-1 are valid for all control sources (Immediate, External, Timer, Manual, or Bus).*

With manual delay selected, the user can set the delay period from 0 seconds to 99 hours, 99 minutes, 99.999 seconds. However, if you set a delay shorter than the corresponding auto delay period, measurement uncertainty increases (noisy and/or unsettled readings may result).

Ratio/Chan Average Delay — With ratio or channel average enabled, a delay is typically used to keep the channel relays from cycling too fast. The default delay period is 0.5 seconds but can be set from 0 to 999999.999 seconds using remote programming (see Section 4 for details). Ratio and channel average are covered in Section 4.

NOTE *After the delay periods for auto or manual delay and ratio/chan average delay have expired, operation proceeds into the Device Action block to take a reading.*

NOTE *Timer control source — Keep in mind that for a timer controlled scan, the timer started when the scan started. If the timer interval has not yet elapsed, the rest of the timer interval will be applied after the Device Action.*

Device action

The channel measurement process is performed at this block. If repeat filter is enabled, the filter process is also performed.

Reading count

NOTE *For both STEP and SCAN, the reading count specifies the number of readings to store in the buffer.*

STEP operation — The reading count specifies the number of channels to scan. This can be equal to, less than, or greater than the number of channels in the scan list. The last scanned channel remains closed. If you again start the scan, it will start at the next channel.

If the reading count is set to infinity (INF), the scan will continuously repeat until you stop it.

NOTE *One counter is used for STEP operation. As shown in Figure 6-1, reading count sets the Trigger Counter.*

SCAN operation — When a scan is started, one or more complete scans will be performed. The number of channels in the scan list determines the number of channels for each scan. The reading count determines the number of scans to perform and is best explained by an example. Assume there are 10 channels in the scan list. If you set the reading count to 10 or less, one scan of the 10 channels will be performed. If you set the reading count to any value from 11 to 20, two scans will be performed. A reading count from 21 to 30 gives you three scans, and so on.

If the reading count is set to infinity (INF), the scan will continuously repeat until you stop it.

NOTE *As shown in Figure 6-2, two counters are used for SCAN operation. The Trigger counter controls the number of scans, and the Sample Counter controls the number of channels for each scan. The number of channels in the scan list and the programmed reading count automatically sets the Trigger Counter and the Sample Counter.*

NOTE *The Sample Count is equal to the scan list length. For example, if channels 101, 102, and 103 are programmed to be scanned, the Sample Count is 3.*

Output trigger

STEP operation — After each channel is scanned, an output trigger is applied to the rear panel Trigger Link connector.

SCAN operation — After all channels in the scan list are scanned, an output trigger is applied to the rear panel Trigger Link connector.

Scan configuration

NOTE *The instrument is always configured to run a scan. On power-up, each available channel uses the power-on default setup. For example, for factory power-on default settings, and two Model 7700s installed, the instrument will scan channels 101 through 220 when the scan is run. See Section 1 for details on power-on default settings.*

There are two scan configurations; simple and advanced. When you configure the simple scan, the instrument uses the present instrument setup for each channel in the scan. For the advanced scan, each channel can have its own unique setup. As explained in "Trigger models," there is a user-set delay (auto or manual) that is in effect for both the simple and advanced scan.

Channel setup considerations

Rel — In order to use an acquired rel value for an advanced scan channel, the rel value has to be acquired with the instrument in the normal measurement state. Details to set rel for scan channels are provided in Section 4 (see "Relative"). Scanning examples (front panel and remote programming) at the end of this section demonstrate how to set rel values for scan channels.

Filter — The moving filter cannot be used in a scan; only the repeat filter can be used. If you configure a channel (or channels) to use the moving filter, the filter will be off when the scan is run. See Section 3 for details on filter.

Hold — Reading hold cannot be used with scanning. Do not set up a scan channel to use hold and do not run a scan with hold enabled.

NOTE *When in the scan setup menu, use the edit keys (◀, ▶, ▲, and ▼) to make selections and set values. Displayed selections and settings are entered by pressing the ENTER key.*

Scan reset

From the scan configuration menu, you can reset the scan configuration to the default setup for a simple scan.

For the Model 7700 switching module, channels 21 and 22 are turned off (not used), and channels 1 through 20 are configured as follows:

Function - DCV
Range - Auto
Rate - Slow
All other multimeter features and functions are disabled.

When the scan is run by pressing STEP or SCAN, channels 1 through 20 will be scanned and the 20 DCV readings will be stored in the buffer.

Perform the following steps to reset the scan configuration:

1. Press SHIFT and then CONFIG to enter the scan configuration menu.
2. Press the ▲ or ▼ key to display "INT: RESET", and press ENTER.

After briefly displaying "LIST RESET" the instrument returns to the normal measurement state.

Simple scan

For a simple scan, you specify a starting channel (MIN CHAN) and an ending channel (MAX CHAN) for the scan. These settings determine the number of channels in the scan. For example, if you set MIN CHAN to 101 and MAX CHAN to 110, there will be 10 channels in the scan list.

The starting channel number must be lower than the ending channel number. If you enter an invalid value, the message "TOO SMALL" or "TOO LARGE" will be displayed briefly. The displayed channel number will default to the lowest available channel (i.e., 101) or the highest available channel (i.e., 220).

Perform the following steps to configure a simple scan:

1. While in the normal measurement mode, set up the instrument for your test. This setup will be used for all selected channels in the scan.
2. Press SHIFT and then CONFIG to access the scan setup menu.
3. Press the ▲ or ▼ key to display "INT: SIMPLE", and press ENTER.
4. Set the minimum channel (MIN CHAN) for the scan and press ENTER.
5. Set the maximum channel (MAX CHAN) for the scan and press ENTER.
6. Set timer ON or OFF and press ENTER. See "STEP and SCAN keys" for details on timer operation.
7. If you enabled the timer, set the timer interval using the hour/minute/second format. The timer can be set from 0.001 sec (00H:00M:00.001S) to 99 hrs, 99 min, 99.999 sec (99H:99M:99.999S). With the desired interval displayed, press ENTER.
8. The displayed reading count (RDG CNT) sets the number channels to scan (STEP) or the number of scans to run (SCAN). You can change the reading count to any finite value from 2 to 55000, or you can select infinite (continuous scanning). To select infinite, set the reading count to 00000 to display INF. See "Trigger models, Reading count" for details on reading count. With the desired reading count setting displayed, press ENTER to return to the normal measurement display state.

Advanced scan

For an advanced scan, each enabled channel can have its own unique setup. Channels that are disabled are excluded from the scan list.

When you enter the channel setup menu, the displayed information indicates the present setup for the selected channel. The position of the decimal point in the "SETUP" message indicates present range. Examples:

S.ETUP	V:101	1V range for channel 101. If the AC annunciator is off, the function is DCV. If it is on, ACV is selected.
SE.TUP	KΩ:102	10kΩ range for channel 102. If the 4-wire annunciator is off, the function is Ω2. If it is on, Ω4 is selected.
SET.UP	mA:121	100mA range for channel 121. If the AC annunciator is off, the function is DCI. If it is on, ACI is selected.
SETUP	°C:103	TEMP function selected for channel 103.
SETUP	HZ:104	FREQ function selected for channel 104.
SETUP	S:105	PERIOD function selected for channel 105.
SETUP	PR:111	For the Model 7700, channel 111 is paired to channel 101, and cannot be changed. Channel pairing occurs when Ratio or Channel Average is enabled, or when a 4-wire function (Ω4 or 4-wire RTD TEMP) is selected.

The annunciators indicate which of the other instrument settings are enabled for the selected channel. When you edit settings for the selected channel (auto range, rel, rate, etc.) the related annunciators will turn on/off.

Advanced scan setup notes

1. The CHAN annunciator is on while in the scan setup menu.
2. For some channel-specific setups, you have to configure them from a menu. For example, to set up and enable mX+B, you have to use MATH menu. While in that menu, the CHAN annunciator will flash to indicate that you are editing the mX+b math setup for that channel in the scan list. When you exit from the mX+b setup menu, the CHAN annunciator stops flashing.
3. Paired channels — A paired channel function or operation can only be selected for a primary channel. For the Model 7700, channels 1 through 10 are the primary channels. Trying to select a paired channel function or operation for channels 11 through 22 will result in "INVALID CHAN".
4. Function changes — When you press a function key, the selected channel assumes the mainframe setup for that function. Also, available channels (for the specified slot) that follow will also assume that setup. Model 7700 example: If you press DCV for channel 101, channels 101 through 120 will assume the DCV setup. Note that channels for slot 2 are not affected.

When you press the Ω4 function key for a primary channel, the subsequently paired channels will be displayed briefly. Model 7700 example: If you press Ω4 for channel 108, channels 109 and 110 will also assume the Ω4 function, and the message "118-120 PRD" will be displayed to indicate the paired channels.

A channel that is paired to a primary channel is not affected by function changes. Model 7700 example: Assume channel 102 is paired to channel 112. Now select channel 103 and press DCV. All following channels, except channel 112, will assume the DCV setup. Channel 112 remains paired to channel 102. However, if you select channel 101 and press DCV, channel 102 will change to DCV and not be paired to channel 112 anymore. Therefore all 20 channels will assume the DCV setup.

5. Setting changes — When you press a key to change a setting (i.e., range, rel, digits, etc.), only the selected scan channel is affected. Model 7700 example: If you make a range change for channel 103, the range settings for other channels are not affected.

Advanced scan setup procedure

Step 1 Select the advanced scan configuration menu

a. Press SHIFT and then CONFIG to access the scan setup menu.
b. Press the ▲ or ▼ key to display "INT: ADVANCED", and press ENTER.

Step 2 Edit scan channels

a. Use the ◀ or ▶ key to select channel 101:

   SETUP V:101 (factory default)

b. You can disable the channel or use it in the scan. Perform step a or step b:
   a. If you do not want to use the channel, press SHIFT and then CH-OFF to disable the channel. Available channels that follow will also disable. Note, however, that channels for the other slot are not affected.
   b. If you want the channel in the scan, you can either use the presently selected function or select a valid measurement function. When you press a function key (i.e., DCV), the channel assumes the setup of the selected function. Available channels that follow will assume the same setup. Note, however, that channels for the other slot are not affected.

NOTE *For the Model 7700, DCI and ACI cannot be selected for channels 101 through 120, and channels 201 through 220. DCI and ACI are the only functions that can be set for channels 121, 122, 221, and 222.*

c. If you did not disable the channel, make your setup changes (if any) for the selected function. These changes do not affect the following channels.
d. Using the ◀ or ▶ keys to select the channel, repeat steps 2B and 2C to set other channels.
e. When finished setting up channels, press ENTER to proceed on to set up triggering.

NOTE *The remaining steps are used to check or change the setups for triggering, timer, and reading count. If you are not going to make changes to any of those setups, you can exit from the scan setup menu by pressing EXIT twice. The instrument returns to the normal measurement mode.*

Step 3 Enable immediate scan

The present state of immediate scan (IMM SCAN) is displayed; Y (yes, which is the factory and *RST default) or N (no). With immediate scan enabled, the scan will start when you press the STEP or SCAN key. Use the ▲ or ▼ key to display IMM SCAN: Y, and press ENTER.

NOTE *Disable immediate scan (IMM SCAN: N) when you wish to use a monitored reading limit to trigger the start of the scan. This technique to start a scan is covered later in this section (See "Scan operation, Reading limit triggered scan").*

Step 4 Timer controlled scan

The present state of the TIMER will be displayed; OFF or ON. If you do not wish to use the timer, use the ▲ or ▼ key to display TIMER? OFF (which is the factory and *RST default), and press ENTER.

To use the timer, use the ▲ or ▼ key to display TIMER? ON and press ENTER. The timer interval is set using the hour/minute/second format. The timer can be set from 0.001 sec (00H:00M:00.001S) to 99 hr, 99 min, 99.999 sec (99H:99M:99.999S). With the desired interval displayed, press ENTER.

Step 5 Set the reading count

The displayed reading count (RDG CNT) sets the number channels to scan (STEP) or the number of scans to run (SCAN). You can change the reading count to any finite value from 2 to 55000, or you can select infinite (continuous scanning). To select infinite, set the reading count to 00000 to display INF. With the desired reading count setting displayed press ENTER. The instrument returns to the normal measurement mode.

See "Trigger models, Reading count" for details on reading count.

Setting delay

As shown in Figure 6-1 and Figure 6-2, an auto delay or manual delay occurs before each channel is measured. With auto delay selected, the delay period depends on function and range (see Table 7-1). With manual delay selected, the delay period can be set from 0 secs to 99 hrs, 99mins, 99.999 secs.

Perform the following steps to set auto or manual delay:

1. With the instrument in the normal measurement display state, press SHIFT and then DELAY.
2. Press ▲ or ▼ to display AUTO (auto delay) or MAN (manual delay), and press ENTER.

3. If you selected MAN, you will be prompted to set the delay in the hour/minute/second time format. Use the ◀, ▶, ▲, and ▼ keys to set the delay, and press ENTER.

For remote programming, the :TRIGer:DELay <NRf> and :TRIGger:DELay:AUTO <b> commands are used to set the delay. See Table 6-1 for details.

NOTE *The delay for ratio and channel average can only be set using remote programming (see Table 4-3).*

Monitor channel

While in the normal measurement state, a scan list channel can be used to monitor readings. When a channel is selected to be the monitor, it will assume the setup of the scan list channel.

NOTE *If you change the setup while a monitor channel is closed, that setup will be copied to that channel in the scan list.*

When a scan is started, the first channel in the scan list will be briefly displayed. While the scan is in progress, the display will only show the reading(s) for the monitor channel. After the last channel is scanned, the scan will disable with the monitor channel closed.

Monitor can be used with limit testing to trigger the start of a scan. When the monitor detects that a set reading limit has been reached, the scan is triggered to start. The detailed procedure to perform a monitor scan is provided in "Scan operation."

NOTE *The monitor channel must be a channel that is in the scan list. If the monitor channel is removed from the scan list, the lowest channel in the scan list will become the monitor channel.*

To set monitor, the instrument can be in the normal measurement state or enabled while in the advanced scan menu. There are two methods to select a monitor channel; method 1 selects it while a channel is closed, and method 2 selects it with no channels closed.

NOTE *The monitor channel must be a channel that is in the scan list.*

Method 1:

1. Use the CLOSE key or the ◀ and ▶ keys to close the channel that you want to be the monitor.
2. Press SHIFT and then MONITOR (MON annunciator turns on).

Method 2:

1. If a channel is closed, press OPEN to open it.
2. Press SHIFT and then MONITOR.
3. Use the ◀, ▶, ▲, and ▼ keys to display the monitor channel (i.e., MONITOR 101), and press ENTER. The monitor channel closes and the MON annunciator turns on.

To disable monitor, again press SHIFT and then MONITOR (MON annunciator turns off).

Notes:

1. Once enabled, you can change the monitor channel using the CLOSE key or the ◀ and ▶ keys.
2. If you open the monitor channel, the monitor does not disable but it does become inactive (MON annunciator turns off). When a channel is closed, monitor becomes active (MON annunciator turns on).
3. While in the normal measurement state, the present monitor channel dictates which channel in the scan list is the monitor. Therefore, if you change the monitor channel, the scan list monitor channel also changes.
4. When you change the monitor channel while in the normal measurement state, the instrument setup does not change. If you want the monitor channel to assume the setup of the scan list channel, you must disable monitor and then re-enable it.

Auto channel configuration

Auto channel configuration allows you to recall scan list setups. With auto channel configuration enabled, a closed channel assumes the scan list setup. With this feature, you can inspect the channel setups of the scan, or "manually" scan channels.

As with normal operation, when you use the ◀, ▶, or CLOSE to close a channel (or channel pair), any other closed channels are first opened.

Perform the following steps to enable or disable auto channel configuration.

1. Press SHIFT and then SETUP.
2. Use the ▲ or ▼ key to display the auto configuration (CH AUTOCFG) setting; N (no) or Y (yes).
3. Press the ▶ key to place the cursor on the present setting (N or Y), and press the ▲ or ▼ key to change the setting.
4. Press ENTER to return to the normal measurement state.

Saving setup

Up to four instrument setups can be saved in memory using the SHIFT > SAVE menu (SAV0, SAV1, SAV2, and SAV3). A user-saved setup can also be used as the power-on setup. A user-saved setup can be restored from the SHIFT > SETUP menu. Details on user-setups are covered in Section 1.

Auto scan

When auto scan is enabled, the scan operation is saved in memory. If power to the Model 2700 is interrupted, the scan will resume when power is restored. With auto scan enabled, the last scan setup becomes the power-on setup. It takes precedence over the factory, *RST or user-saved power-on setup.

Perform the following steps to set auto scan.

1. While in the normal measurement state, press SHIFT and then SETUP.
2. Use the ▲ and ▼ keys to display the auto scan (AUTOSCAN) setting; N (no) or Y (yes).
3. To change the setting, press ▶ to place the cursor on the setting (N or Y) and press ▲ or ▼ to change the setting.
4. Press ENTER to exit from the menu structure.

NOTE *If during the power-up sequence the Model 2700 detects a card ID change for any slot, auto scan configuration will disable, and an interrupted scan will not be resumed. Error +517 occurs (cannot resume scan) to indicate that the scan has been disabled. The instrument assumes the normal power-on setup.*

NOTE *The Model 7706 does not support auto scan. Trying to enable auto scan with a Model 7706 card installed will cause error -221 (settings conflict).*

Scan operation

A basic scan is controlled solely by the STEP and SCAN keys. When one of these keys is pressed, the STEP or SCAN operation will be performed. For the manual/external trigger scan, the TRIG key or triggers received from another instrument starts the STEP or SCAN operation. For the monitor scan, a channel monitors readings. When a set reading limit is reached, STEP or SCAN will start.

Basic scan

Perform the following steps to run the presently configured scan:

1. **To start the scan, press STEP or SCAN.**

   The STEP or SCAN annunciator turns on, and channels are scanned from the lowest to highest number channel. Channels that are turned off will not be scanned.

   Keep in mind that the Timer Delay for STEP occurs between channels, while the Timer Delay for SCAN occurs between scans. If the timer is off, both scans will run at the same speed.

With reading count set to a finite value, the last channel scanned will open and the first channel in the scan list will close. Keep in mind that the scan is still enabled (STEP or SCAN annunciator on). When you press STEP or SCAN, the scan will continue starting with the next channel.

With reading count set to infinite, the scan will keep repeating.

NOTE *While the scan is enabled (STEP or SCAN annunciator on), most front panel keys are inoperative and will cause the message "HALT SCANNER" to be displayed.*

2. **To disable the scan, press SHIFT and then HALT.**

Buffer

To recall scanned readings stored in the buffer, press RECALL and use the ◀, ▶, ▲, and ▼ keys to navigate through the buffer. Note that the buffer can be read while the instrument is storing readings. See Section 5 for details on recalling buffer readings. When finished, make sure to exit from buffer recall by pressing the EXIT key.

Manual/external trigger scan

The only difference between a manual/external trigger scan and the basic scan is control. The basic scan runs as soon as the STEP or SCAN key is pressed. The manual/external trigger scan is controlled by the front panel TRIG key or by triggers received from another instrument.

NOTE *For the following procedure, the Model 2700 can be triggered by pressing the TRIG key or by receiving a trigger pulse from another instrument. Section 7 provides details on triggering.*

1. If the scanner is presently enabled (STEP or SCAN annunciator on), press SHIFT and then HALT to disable it.
2. Press the EX TRIG to place the instrument in the external triggering mode. The TRIG annunciator turns on and the reading is blanked (-------).
3. Press STEP or SCAN to enable the scan (STEP or SCAN annunciator turns on).
4. The TRIG key or input triggers control the scan as follows:

   STEP operation — In general, each time the Model 2700 is triggered, one channel is scanned. When the STEP key is pressed to enable the scan, the first channel in the scan list closes. When the first trigger occurs, a measurement is taken, the channel opens and the next channel closes. This process continues for each channel in the scan. After the last channel in the scan list is scanned, the first channel in the scan list closes.

   The reading count determines how many channel measurements will be performed during the scan sequence. If the reading count is greater than the scan list length, operation loops back to the beginning of the scan list and continues.

   After a scan sequence (as determined by the reading count) is completed, the scan remains enabled (STEP annunciator on), but the Model 2700 goes into the idle state. If you wish to repeat the scan sequence, you will have to first take the Model 2700 out of idle. This can be done by pressing the STEP (or TRIG) key.

SCAN operation — In general, when the Model 2700 is triggered, a complete scan of all the channels in the scan list is performed. When the SCAN key is pressed to enable the scan, the first channel in the scan list closes. When a trigger occurs, one scan of the scan list channels is performed. After the last channel is scanned, the first channel in the scan list will close.

Reading count determines how many scans will be performed (see "Trigger models, reading count"). If programmed for another scan, it will start when another trigger occurs.

After the last scan is completed, the scan remains enabled (SCAN annunciator on), but the Model 2700 goes into the idle state. If you wish to repeat the scans, you will have to first take the Model 2700 out of idle. This can be done by pressing the SCAN (or TRIG) key.

5. When finished, press SHIFT and then HALT to disable the scan, and press EX TRIG to take the Model 2700 out of the external triggering mode.

Monitor scan (analog trigger)

A channel can be assigned as a monitor channel. When the monitor channel detects that a reading limit has been reached, the scan will be triggered to start.

There are four reading limits that can be can be used to trigger the start of the scan; low limit 1 (LLIM1), high limit 1 (HLIM1), low limit 2 (LLIM2), high limit 2 (HLIM2). The scan will start when any enabled reading limit event is detected by the monitor channel. Details on Limits are provided in Section 8.

Perform the following steps to run a monitor scan:

NOTE *The last enabled scan function (STEP or SCAN) will be used for the monitor scan.*

1. Perform Step 1 and Step 2 of the "Advanced scan setup procedure" to set up scan channels. With the channel to be used as the monitor selected, set and enable limits as follows. Note that you only need to set values for limits that are going to be used.
   a. Press SHIFT and then LIMITS to access the limits menu. Note that the CHAN annunciator flashes to indicate that the menu is being used to set up a scan channel.
   b. Use the ◀, ▶, ▲, and ▼ keys to set high limit 1 (HI1), and press ENTER.
   c. Set low limit 1 (LO1), and press ENTER.
   d. Set high limit 2 (HI2), and press ENTER.
   e. Set low limit 2 (LO2), and press ENTER. The instrument returns to the scan setup menu.
   f. Press SHIFT and then ON/OFF to display the present state of LIMITS (ON or OFF). Again, the CHAN annunciator flashes to indicate that the menu is for a scan channel.
   g. Press the ▲ or ▼ key to display "LIMITS:ON" and press ENTER. The instrument returns to the scan setup menu. Note that the HIGH and LOW annunciators are on to indicate that limits are enabled.

   After all scan channels are set up, press ENTER. The present state of IMM SCAN; Y (yes) or N (no).

2. Press the ▲ or ▼ key to display IMM SCAN: N and press ENTER.
   a. Press the ▲ or ▼ key to enable or disable low limit 1 (LLIM1 SCAN:N/Y), and press ENTER.
   b. Press the ▲ or ▼ key to enable or disable high limit 1 (HLIM1 SCAN:N/Y), and press ENTER.
   c. Press the ▲ or ▼ key to enable or disable low limit 2 (LLIM2 SCAN:N/Y), and press ENTER.
   d. Press the ▲ or ▼ key to enable or disable high limit 2 (HLIM2 SCAN:N/Y), and press ENTER.
3. Finish configuring the scan by performing Step 4 and Step 5 of the "Advanced scan setup procedure."

NOTE *For a remote programmed monitor scan, use the :ROUTe:MONitor:POINts command to specify the number of channels to scan (see Table 6-1).*

4. While in the normal measurement state, select and enable the monitor channel as explained in "Scan configuration, Monitor channel."

   When the reading limit for the monitor channel is reached, the scan will be triggered to start. When the monitor channel is scanned, the display will show the reading that triggered the scan.

   If the reading limit event is still present on the monitor channel when the scan finishes, the scan will be triggered to run again. Note that the scan can also be run by pressing STEP or SCAN.
5. To disable the monitor scan, perform the following steps:
   a. To disable monitor, press SHIFT and then MONITOR (MON annunciator turns off).
   b. To disable limits, press SHIFT and then ON/OFF. Press ▲ or ▼ to display "LIMITS: OFF" and press ENTER.

Remote programming — scanning

NOTE *Scanning examples (remote programming and front panel operation) are provided at the end of this section.*

Trigger model

The trigger model for bus operation is shown in Figure 6-2. Bus operation is similar to front panel SCAN operation, with the following significant differences:

Idle — As shown in Figure 6-2, the instrument goes into the idle state (measurements halted) after the last scan channel is measured. For front panel operation, the instrument stays in idle until the next scan is started. For bus operation, the instrument will not stay in idle unless continuous initiation is disabled. There are two commands to disable continuous initiation:

```
:INITitate:CONTinuous OFF      ' Disable continuous initiation.
*RST                           ' Restore *RST defaults.
```

The instrument will remain in idle until it receives an initiate command. Typical commands to initiate one scan cycle include:

```
:INITiate                ' Initiate one scan cycle.
:READ?                   ' Initiate one scan cycle and request "sample" readings.
```

More information on using these commands is provided by Reference C that follows Table 6-1.

Control sources — For bus operation, there are two additional control sources; Bus and Manual. For the Bus control source, scan operation is controlled by bus triggers (i.e., *TRG) or by using the TRIG key. For the Manual control source, event detection is controlled solely by the TRIG key. Note that the instrument has to be in local in order to use the TRIG key. The LOCAL key takes the instrument out of remote.

Trigger and sample counters — For front panel SCAN operation, the number of channels in the scan list and the programmed reading count automatically sets the trigger and sample counters. For remote operation, these two counters are set by the :TRIGGer:COUNt and :SAMPle:COUNt commands.

NOTE *To set sample count >1, continuous initiation must be disabled (see "Idle"). Also note that only sample count readings are stored in the buffer. See Section 7 for detailed information on the trigger model.*

Channel setup

The <clist> parameter is used to set up scan channels. For example, the following examples show how to set up scan channel 101:

```
FUNC 'VOLT', (@101)      ' Set 101 for DCV.
VOLT:RANG 10, (@101)     ' Set 101 for 10V range.
VOLT:DIG 4.5, (@101)     ' Set 101 for 4½ digit resolution.
VOLT:NPLC 3, (@101)      ' Set 101 rate for 3 PLC.
```

Buffer

For front panel scanning, the reading count specifies the number of readings to store in the buffer. For remote scanning, the sample count specifies the number of readings to store in the buffer.

Initially, the buffer must be empty before sending :INITiate or :READ? to take the instrument out of idle. The following command clears the buffer:

```
:TRACe:CLEar             ' Clear buffer.
```

Scanning commands

Scanning commands are listed in Table 6-1. Additional information on these commands follow the table.

NOTE *Query commands and optional command words are not included in Table 6-1. The Unabridged SCPI tables are provided in Section 14.*

Table 6-1
Scanning commands

Commands	Description	Default	Ref
Scan commands:			
:ROUTe:SCAN <clist>	Specify list of channels to be scanned.		
:ROUTe:SCAN:TSOurce <list>	Select trigger(s) to start scan; <list> = IMMediate, or HLIMit1, LLIMit1, HLIMit2, LLIMit2.	IMM	A
:ROUTe:SCAN:NVOLatile <b>	Enable or disable auto scan; <b> = ON or OFF.	(Note 1)	
:ROUTe:SCAN:LSELect <name>	Enable/disable scan; <name> = INTernal (on) or NONE (off).	OFF	
:ROUTe:MONitor <clist>	Specify one channel to be monitored.		B
:ROUTe:MONitor:POINts <NRf>	Specify number of channels to scan; <NRf> = 2 to 55000.	(Note 3)	C
:ROUTe:MONitor:STATe <b>	Enable/disable monitor; <b> = ON or OFF.	OFF	
:ROUTe:MONitor:DATA?	Returns the most recent monitor reading.		
Limits commands:			
:CALCulate3:LIMit1:UPPer <n>	Set high limit 1 for monitor; <n> = -4294967295 to +4294967295.	1.0	
:CALCulate3:LIMit1:LOWer <n>	Set low limit 1 for monitor; <n> = -4294967295 to +4294967295.	-1.0	
:CALCulate3:LIMit2:UPPer <n>	Set high limit 2 for monitor; <n> = -4294967295 to +4294967295.	2.0	
:CALCulate3:LIMit2:LOWer <n>	Set low limit 2 for monitor; <n> = -4294967295 to +4294967295.	-2.0	
:CALCulate3:LIMit1:STATe <b>	Enable/disable limit 1 test; <b> = ON or OFF.	OFF	
:CALCulate3:LIMit2:STATe <b>	Enable/disable limit 2 test; <b> = ON or OFF.	OFF	
Trigger commands:			
:TRIGger:SOURce <name>	Select control source; <name> = IMMediate, TIMer, MANual, BUS, or EXTernal.	IMM	
:TRIGger:TIMer <n>	Set timer interval in sec; <n> = 0.001 to 999999.999.	0.1	
:TRIGger:COUNt <NRf>	Set trigger count; <NRf> = 1 to 9999 or INF.	(Note 2)	D
:TRIGger:DELay <n>	Set delay in sec; <n> = 0 to 999999.999.	0	
:TRIGger:DELay:AUTO <b>	Enable/disable auto delay; <b> = ON or OFF.	ON	
:SAMPle:COUNt <NRf>	Set sample count; <NRf> = 1 to 55000.	1	D
:SAMPle:COUNt?	Query sample count.		
:INITiate:CONTinuous <b>	Enable/disable continuous initiation; <b> = ON or OFF.		E
:INITiate	Initiate one scan cycle.		E
:READ?	Initiate one scan cycle and request sample readings.		E

Table 6-1 (Continued)
Scanning commands

Commands	Description	Default	Ref
Buffer commands:			
:TRACe:DATA?	Read buffer readings.		
:TRACe:CLEar	Clear buffer.		
Channel list parameter: <clist> = (@SCH) where: S = Mainframe slot number (1 or 2) CH = Switching module channel number (must be 2 digits) Examples: (@101) = Slot 1, Channel 1 (@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3 (@101:110) = Slot 1, Channels 1 through 10			

1. Not affected by *RST and :SYSTem:PRESet. Front panel factory default is OFF.
2. *RST sets count to 1, and :SYSTem:PRESet sets count to INFinity.
3. The default value depends on which switching module is installed.

Reference

A. ROUTe:SCAN:TSOurce <list>

<list> = IMMediate
= HLIMit1, HLIMit2, LLIMit1, LLIMit2

As with front panel operation, the scan can start immediately when it is enabled and triggered, OR it can be started by a reached reading limit detected by the monitor channel. For immediate, the IMMediate command must be the only parameter in the list. To use reading limits, each limit must be separated by a comma (,). Examples:

```
ROUT:SCAN:TSO  IMM              ' Start scan when it is enabled and triggered.
ROUT:SCAN:TSO  HLIM1, LLIM1     ' Enable high limits 1 and low limits 1.
```

Note that any reached limit will start the scan.

B. ROUTe:MONitor — The channel that you specify as the monitor must be a channel that is in the scan list. If it is not, the first channel in the scan list will automatically become the monitor channel.

If the clist has more than one channel, error -223 (Too much data) occurs and the command is not executed.

C. ROUTe:MONitor:POINts <NRf> — Use this command to specify the number of channels to scan each time the monitor scan is triggered to start. For example, assume the monitor scan list has 10 channels. To scan that list once, send :ROUT:MON:POIN 10. To scan that list twice, use parameter value 20. For three scans, send parameter value 30, and so on.

D. SAMPle:COUNt and TRIGger:COUNt — Sample count specifies the number of readings to scan and store in the buffer, while the trigger count specifies the number of scans to perform.

   If the sample count is greater than the number of channels in the scan list (scan list length), operation wraps around to the beginning of the scan list and continues. For example, assume the scan list is made up of channels 101, 102, and 103, and the sample count is set to 4. After channels 101, 102, and 103 are scanned, operation loops around to scan channel 101 again. The first and last readings in the buffer will be channel 101.

   When performing multiple scans (trigger count >1), sample readings overwrite the readings stored for the previous scan.

   Continuous initiation must be disabled in order to set the sample counter >1 (see Reference C).

E. INITiate:CONTinuous, INITiate and READ? — In order to initiate a single scan cycle using INITiate or READ?, continuous initiation must be disabled. If you send INIT or READ? with continuous initiation enabled, error -213 (Init ignored) will occur.

   You cannot use READ? or INITiate if sample count >1, AND there are readings stored in the buffer (error -225, out of memory). Either set the sample count to one or clear the buffer (TRACe:CLEar).

Scanning programming example

The following program will scan 10 channels (101 through 110):

```
TRAC:CLE                        ' Clear buffer.
INIT:CONT OFF                   ' Disable continuous initiation.
TRIG:SOUR IMM                   ' Select the immediate control source.
TRIG:COUN 1                     ' Set to perform one scan.
SAMP:COUN 10                    ' Set to scan 10 channels.
ROUT:SCAN (@101:110)            ' Set scan list channels; 101 through 110.
ROUT:SCAN:TSO IMM               ' Start scan when enabled and triggered.
ROUT:SCAN:LSEL INT              ' Enable scan.
READ?                           ' Trigger scan and request the readings.
```

Scanning examples

The following scanning examples assume that the Model 7700 switching module is installed in slot 1 of the mainframe.

Tables are used for the procedure steps to configure and run scan examples. The left side of the table provides the front panel procedure, while the right side shows the equivalent remote programming commands. Where appropriate, menu sequences are provided to summarize a front panel operation or selection: For example:

SHIFT SETUP > RESTORE: FACT

For the above menu sequence, press SHIFT and then SETUP to access the menu, use the edit keys (◀, ▶, ▲, and ▼) to display RESTORE: FACT, and then press ENTER to select it.

External trigger scan

For this example, an external instrument is used to trigger the start of the 2-channel scan. Trigger pulse requirements and trigger cable connections are covered in Section 7.

NOTE *For this example, the front panel TRIG key can be used in place of an external input trigger. Each time the TRIG key is pressed, the 2-channel scan will run.*

One channel (101) measures temperature and the other channel (102) measures resistance. The two readings are stored in the buffer. Each time the scan is run, the two readings will be appended (added) to the buffer.

A type K thermocouple is used to measure temperature. Since the internal cold (reference) junction of the Model 7700 is being used, the thermocouple can be connected directly to the screw terminals of the switching module.

Operation

A simplified model of external trigger scan operation is shown in Figure 6-3, while the procedure steps and programming commands are listed in Table 6-2.

As shown in the operation model, when the scan is enabled, channel 101 closes and the Model 2700 waits for an external trigger. When the trigger is received, channels 101 and 102 are measured. Operation then returns to the control source where it waits for another trigger.

NOTE *After the scan is enabled (step 5 in Table 6-2), the TRIG key can be used to trigger the scan.*

Figure 6-3
External trigger scan example

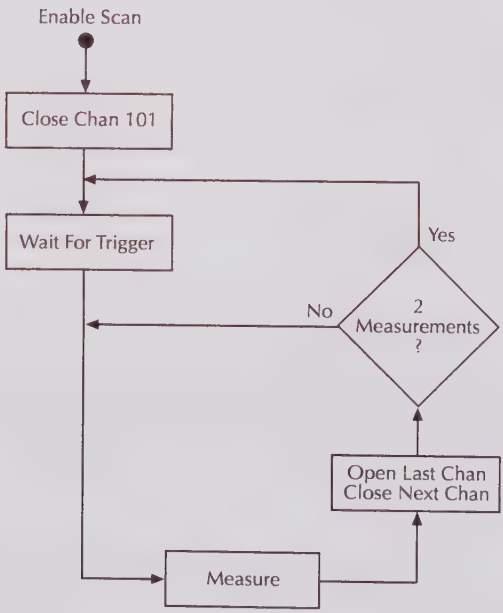


Table 6-2
External trigger scan example

	Front panel operation	Remote programming
1	Restore defaults:	
	Restore defaults (SHIFT SETUP > RESTORE: FACT).	`*RST`
2	For front panel operation, proceed to step 3.	
	For remote programming, clear buffer and disable buffer auto clear:	`TRAC:CLE` `TRAC:CLE:AUTO OFF`
3	Configure advanced scan:	
	(SHIFT CONFIG > ADVANCED):	
a	Channel 101:	
	SelectTEMP function.	`FUNC 'TEMP',(@101)`
	Configure temperature (SHIFT SENSOR):	
	Select °C units (UNITS: C).	`UNIT:TEMP C`
	Select Thermocouple sensor (SENS: TCOUPLE).	`TEMP:TRAN TC,(@101)`
	Select type K thermocouple (TYPE: K).	`TEMP:TC:TYPE K,(@101)`
	Select internal reference junction (JUNC: INT).	`TEMP:RJUN:RSEL INT,(@101)`
b	Channel 102:	
	Select Ω2 function.	`FUNC 'RES',(@102)`
	Select 1MΩ range.	`RES:RANG 1e6,(@102)`
c	Disable (off) channels 103 through 122 (SHIFT CH-OFF).	`ROUT:SCAN (@101,102)`
d	Enable immediate scan (IMM SCAN: Y).	`ROUT:SCAN:TSO IMM`
e	Disable timer (TIMER? OFF).	
f	Set reading count to infinity (RDG: INF).	`TRIG:COUN INF` `SAMP:COUN 2`
4	Select external trigger control source:	
	Press EX TRIG.	`TRIG:SOUR EXT`
5	Enable scan:	
	Press SCAN.	`ROUT:SCAN:LSEL INT` `INIT`

Monitor scan

For this example, channel 101 of the Model 7700 is used to monitor temperature. When the temperature reading reaches 30°C, it will start the scan. For this 4-channel scan, channel 101 measures temperature, while channels 102, 103, and 104 measure DCV.

This example uses the Channel Average feature to measure temperature. With channel average enabled, two temperature measurements will be taken; one at channel 101 and another at its paired channel (111). The two measured readings are then averaged to yield a single reading. It is this averaged temperature reading that will start the scan when it reaches 30°C. Refer to Section 4 for details on channel average.

Two type K thermocouples are used to measure temperature. Since the internal cold (reference) junction of the Model 7700 is being used, the thermocouples can be connected directly to the screw terminals of the switching module.

Operation

A simplified model of monitor scan operation is shown in Figure 6-4, while the procedure steps and programming commands are listed in Table 6-3.

In Figure 6-4, notice that there are two modes of operation. While in the monitor mode, the Model 2700 continuously performs temperature measurements. Keep in mind that Channel Average is being used. Therefore each temperature reading is the average of two temperature measurements (one on channel 101 and one on channel 111). As long as the average temperature reading remains below 30°C, the instrument will remain in the monitor mode.

When the temperature reading reaches 30°C, the Model 2700 switches over to the scan mode. Figuratively speaking, it is as if a "finger" presses the SCAN key when the monitor detects that the average temperature is at or above 30°C.

The instrument is configured to scan four channels. The monitor TEMP channel reading and three DCV channel readings are stored in the buffer. After the fourth channel is measured, operation returns to the monitor mode, to again measure temperature. Note that if the average temperature is still at or above 30°C, the "finger" will again press SCAN to start the scan.

Figure 6-4
Monitor scan example

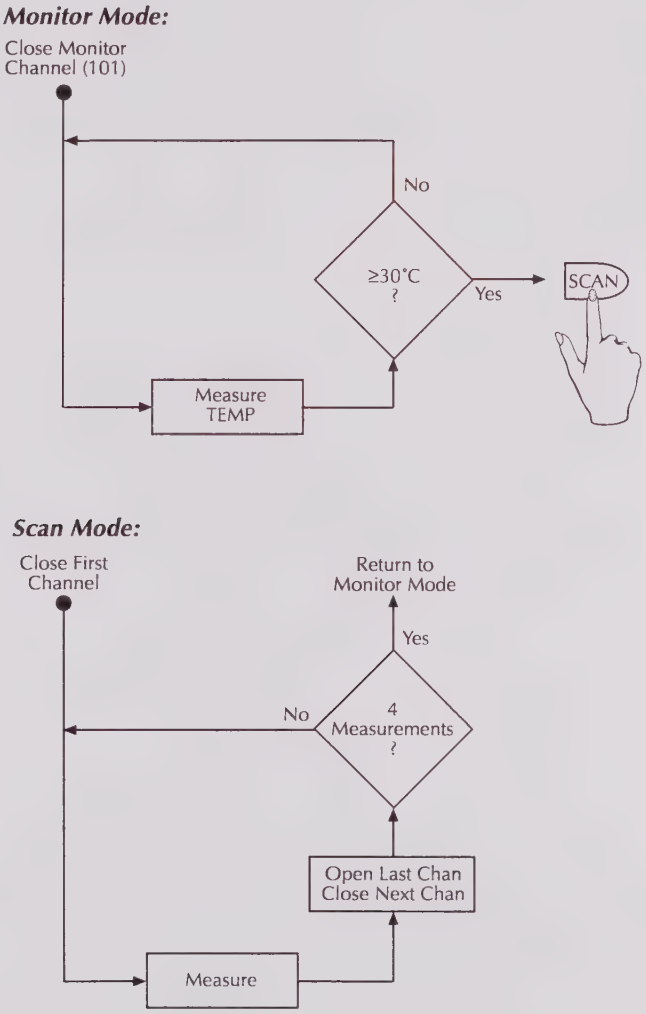


Table 6-3
Monitor scan example

	Front panel operation	Remote programming
1	Restore defaults (SHIFT SETUP > RESTORE: FACT).	`SYST:PRES`
2	For front panel operation, proceed to step 3.	
	For remote programming, clear the buffer:	`TRAC:CLE`
3	Configure advanced scan:	
	SHIFT CONFIG > ADVANCED:	
a	Channel 101:	
	Select TEMP function.	`FUNC 'TEMP',(@101)`
	Configure temperature (SHIFT SENSOR):	
	Select °C units (UNITS: C).	`UNIT:TEMP C`
	Select Thermocouple sensor (SENS: TCOUPLE).	`TEMP:TRAN TC,(@101)`
	Select type K thermocouple (TYPE: K).	`TEMP:TC:TYPE K,(@101)`
	Select internal reference junction (JUNC: INT).	`TEMP:RJUN:RSEL INT,(@101)`
b	Set and enable high limit 1:	
	Set limit to 30 (SHIFT LIMITS > HI1:+30.00000).	`CALC3:LIM1:UPP 30,(@101)`
	Enable (on) limit (SHIFT OFF/ON > LIMITS: ON).	`CALC3:LIM1:STAT ON,(@101)`
	Enable Channel Average (SHIFT CH AVG).	`CAV ON,(@101)`
c	Channel 102, 103, and 104:	
	Select DCV function.	`FUNC 'VOLT',(@102:104)`
	Select 10V range.	`VOLT:RANG 10,(@102:104)`
	Set filter count to 20 (SHIFT TYPE > 020 RDGS).	`VOLT:AVER:COUN 20,(@102:104)`
	Enable filter (FILTER).	`VOLT:AVER:STAT ON,(@102:104)`
d	Disable (off) channels 105 through 222 (SHIFT CH-OFF).	`ROUT:SCAN (@101:104)`
e	Disable immediate scan (IMM SCAN: N), and enable high limit 1 (HLIM1 SCAN:Y).	`ROUT:SCAN:TSO HLIM1`
f	Disable timer (TIMER? OFF).	
g	Set reading count to 4.	`ROUT:MON:POIN 4`
4	Select and enable monitor channel (SHIFT MONITOR >101).	`ROUT:MON (@101)` `ROUT:MON:STAT ON`

7
Triggering

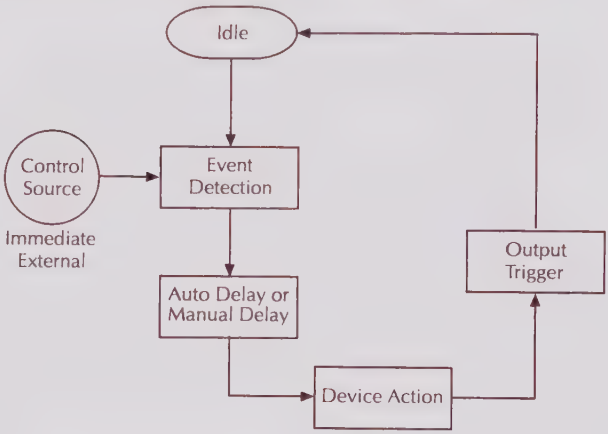
- **Trigger model** — Explains the various components of the front panel trigger model, which controls the triggering operations of the instrument.
- **Reading hold** — Explains the Reading Hold feature which is used to screen out readings that are not within a specified reading window.
- **External triggering** — Explains external triggering which allows the Model 2700 to trigger other instruments, and be triggered by other instruments.
- **Remote programming** — Covers remote operation for triggering including the GPIB trigger model and the commands.

Trigger model

The flowchart in Figure 7-1 summarizes triggering as viewed from the front panel. It is called a trigger model because it is modeled after the SCPI commands used to control triggering. Note that for scanning, the trigger model has additional control blocks. These are described in Section 6.

NOTE *The complete trigger model, which is based on bus operation, is shown and discussed later in this section (see "Remote programming").*

Figure 7-1
Front panel trigger model (without scanning)



Idle

The instrument is considered to be in the idle state whenever it is not performing any measurements or scanning operations. From the front panel, the unit is considered idle at the end of a scan operation when the reading for the last channel remains displayed. To restore triggers, press SHIFT and then HALT.

Once the Model 2700 is taken out of idle, operation proceeds through the trigger model.

Control source and event detection

The control source holds up operation until the programmed event occurs and is detected. The control sources are described as follows:

- **Immediate** — With this control source, event detection is immediately satisfied allowing operation to continue.
- **External** — Event detection is satisfied for any of the following three conditions:
  - An input trigger via the Trigger Link line EXT TRIG is received.

- The front panel TRIG key is pressed. (The Model 2700 must be taken out of remote before it will respond to the TRIG key. Use the LOCAL key or send GTL over the bus.)
- Trigger command (*TRG or GET) received over the bus.

Delay (auto or manual)

A programmable delay is available after event detection. It can be set manually or an auto delay can be used. With auto delay selected, the instrument automatically selects a delay period that will provide sufficient settling for function and autorange changes and multi-phase measurements.

Normal measurement state — With auto delay selected and the External or Bus control source selected, the Model 2700 selects a delay based on the selected voltage range. The auto delay period cannot be adjusted by the user. The auto delays are listed in Table 7-1. With one of the other control sources selected, the auto delay is 0.000s for all functions and ranges.

Scanning — When scanning, the nominal delay will be long enough to allow each switching module channel relay to settle before making the measurement. When scanning, the auto delay times in Figure 7-1 are valid for all control sources.

Table 7-1
Auto delay settings

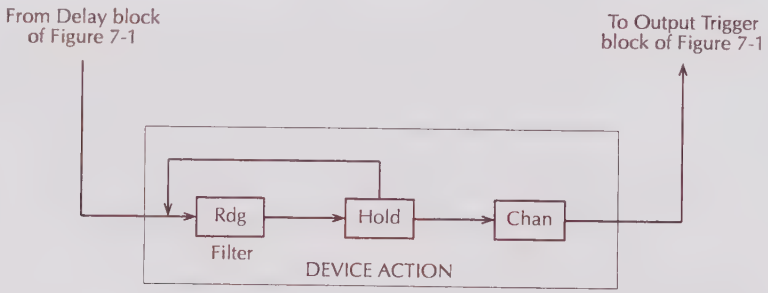
Function	Range and Delay						
DCV	100mV 1ms	1V 1ms	10V 1ms	100V 5ms	1000V 5ms		
ACV	100mV 400ms	1V 400ms	10V 400ms	100V 400ms	750V 400ms		
FREQ and PERIOD	100mV 1ms	1V 1ms	10V 1ms	100V 1ms	750V 1ms		
DCI	20mA 2ms	100mA 2ms	1A 2ms	3A 2ms			
ACI			1A 400ms	3A 400ms			
Ω2, Ω4	100Ω 3ms	1kΩ 3ms	10kΩ 13ms	100kΩ 25ms	1MΩ 100ms	10MΩ 150ms	100MΩ 250ms
Continuity		1kΩ 3ms					
TEMP	The auto delay for thermocouples is 1ms. For thermistors and 4-wire RTDs, the auto delay period is the same as the delay for the resistance range that is used for the measurement.						

The delay function is accessed by pressing SHIFT and then DELAY. The present delay setting (AUTO or MANual) is displayed. Press the ▲ or ▼ key to display the desired setting and press ENTER. If MANual is chosen, also enter the duration of the delay in the hour/minute/second format using the ◀, ▶, ▲, and ▼ keys. The maximum is 99H:99M:99.999S. Press ENTER to accept the delay or EXIT for no change.

Device Action

The primary device action is a measurement. However, the device action block could include the following additional actions (refer to Figure 7-2):

Figure 7-2
Device action



- **Filtering** — If the repeating filter is enabled, the instrument samples the specified number of reading conversions to yield single filtered reading. Only one reading conversion is performed if the filter is disabled, or after the specified number of reading conversions for a moving average filter is reached. After a reading (Rdg) is procured, operation proceeds to Hold.
- **Hold** — The Hold feature is used to screen out reading anomalies. When enabled, the user selects a window and count for Hold. In general, when a reading is outside the window it is rejected; operation loops back to be beginning of the Device Action as shown in Figure 7-2. The hold count specifies how many readings have to be within the window before it is accepted. See "Reading hold (autosettle)" for operation details. After a Hold Reading is acquired, operation proceeds to Channel Closure.
- **Channel Closure** — When scanning, the last device action is channel control. Using the hold feature provides an auto settling time for switching relays. Each open/close transition will restart the hold process and a reading for each channel will not occur until the relay settles.

Output trigger

After the device action, an output trigger occurs and is available at the rear panel Trigger Link connector. This trigger can be used to trigger another instrument to perform an operation (e.g., select the next channel for an external scan).

Reading hold (autosettle)

With hold enabled (HOLD annunciator on), the first processed reading becomes the "seed" reading and operation loops back within the device action block. After the next reading is processed, it is checked to see if it is within the selected hold window (0.01%, 0.1%, 1%, 10%) of the "seed" reading. If the reading is within the window, operation again loops back within the device action block. This looping continues until the specified number (2 to 100) of consecutive readings are within the window. If one of the readings is not within the window, the instrument acquires a new "seed" reading and the hold process continues.

When a hold reading is acquired, an audible beep is sounded (if enabled) and the reading is considered a "true measurement." The reading is held on the display until an "out of window" reading occurs to restart the hold process.

For remote operation, the hold process seeks a new "seed" once it has been satisfied and the reading has been released. For basic front panel operation, the hold process does not seek a new "seed" until the held condition is removed.

NOTE Hold cannot be used when scanning.

Hold example

1. Press SHIFT and then HOLD to display the present window (0.01%, 0.1%, 1%, or 10%).
2. To change the window, press the ▲ or ▼ key to display the desired window.
3. Press ENTER. The present hold count is displayed (2 to 100).
4. To change the hold count, use the ◀, ▶, ▲, and ▼ keys to display the desired count.
5. Press DCV to measure DC voltage.
6. Apply the test signal to the input of the Model 2700. Once the signal becomes stable enough to satisfy the hold condition, the reading is released and the beeper sounds (if enabled).
7. Remove the hold condition by disconnecting the signal from the input. Hold will then seek a new "seed."
8. To disable HOLD, press SHIFT and then HOLD.

Beeper control

The beeper for Hold can be enabled or disabled from the OUTPUT menu as follows:

1. Press SHIFT and then OUTPUT.
2. Use the ▲ or ▼ key to display the present beeper (BEEP) state; NEVER, OUTSIDE, or INSIDE.
3. Perform step A or B:
   a. To enable the beeper, use the ▲ or ▼ key to display OUTSIDE or INSIDE.
   b. To disable the beeper, use the ▲ or ▼ key to display NEVER.
4. Press ENTER. The instrument returns to the normal display state. The instrument returns to the normal measurement state.

External triggering

The EX TRIG key selects triggering from three external sources: trigger link, digital I/O, and the TRIG key. When EX TRIG is pressed, the TRIG annunciator lights and dashes are displayed to indicate the instrument is waiting for an external trigger. From the front panel, press the TRIG key to trigger a single reading. Pressing the EX TRIG key again toggles back to continuous triggers.

The Model 2700 uses two lines of the TRIG LINK rear panel connector as External Trigger (EXT TRIG) input and Voltmeter Complete (VMC) output. The EXT TRIG line allows the Model 2700 to be triggered by other instruments. The VMC line allows the Model 2700 to trigger other instruments.

Line 1 is configured as VMC and line 2 as EXT TRIG. The connector pinout is shown in Figure 7-3.

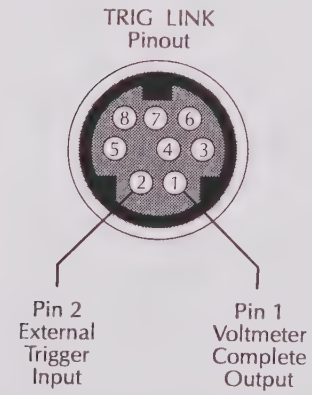
Digital I/O

Pin 6 (Ext Trig) of the Digital I/O can also be used as the external trigger input for the Model 2700. Line 2 of the TRIG LINK is physically connected to pin 6 of the Digital I/O connector.

The Digital I/O also has a hardware interlock line (pin 8) that allows the use of an external circuit to control input triggers. When that line is left open or pulled high (+5V), input triggers are enabled. When pulled low to 0V, input triggers are disabled. When disabled, the Model 2700 will not respond to an input trigger.

Details on the Digital I/O are provided in Section 8.

Figure 7-3
TRIG LINK pinout

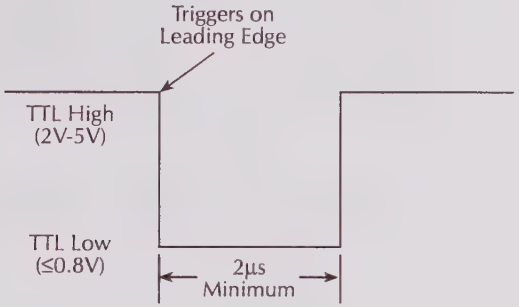


Pin Number	Description
1	Voltmeter Complete Output
2	External Trigger Input
3	No Connection
4	No Connection
5	No Connection
6	No Connection
7	Signal Ground
8	Signal Ground

External trigger

The EXT TRIG input requires a falling-edge, TTL-compatible pulse with the specifications shown in Figure 7-4. In general, external triggers can be used to control measure operations. For the Model 2700 to respond to external triggers, the trigger model must be configured for it.

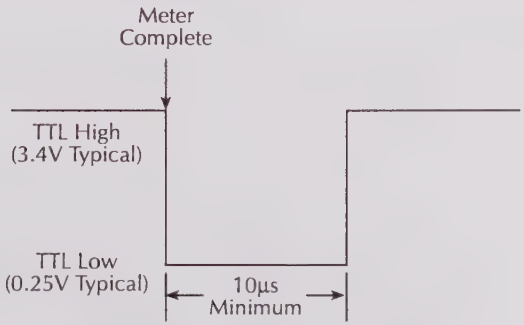
Figure 7-4
Trigger link input pulse specifications (EXT TRIG)



Voltmeter complete

The VMC output provides a TTL-compatible output pulse that can be used to trigger other instruments. The specifications for this trigger pulse are shown in Figure 7-5. Typically, you would want the Model 2700 to output a trigger after the settling time of each measurement.

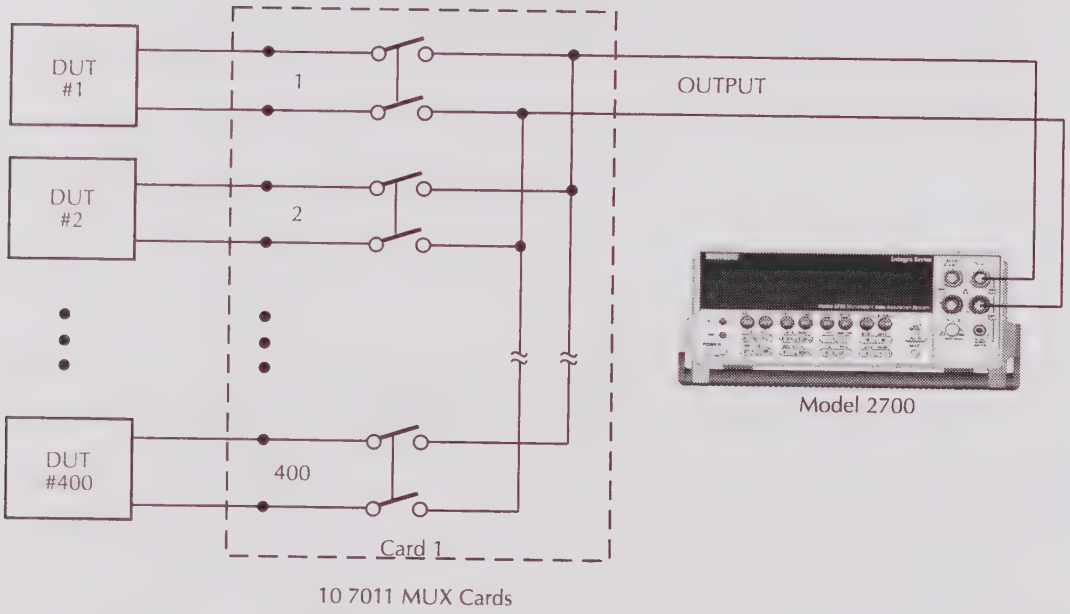
Figure 7-5
Trigger link output pulse specifications (VMC)



External triggering example

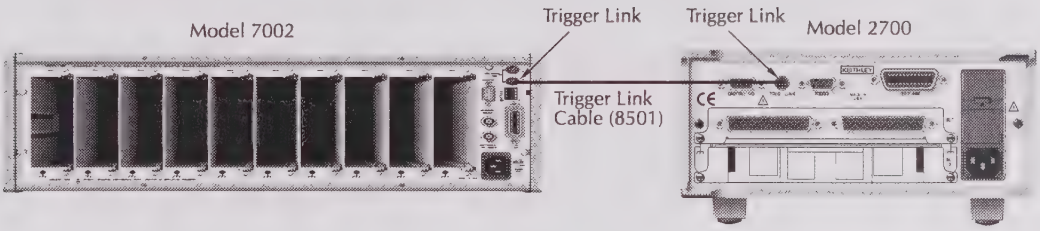
For a test system that requires a large number of switching channels, the Model 2700 can be used with external scanners such as the Keithley Models 7001 and 7002. For example, 10 Model 7011s installed in the Model 7002 can provide up to 400 2-pole channels, as shown in Figure 7-6.

Figure 7-6
DUT test system



The Trigger Link connections for this test system are shown in Figure 7-7. Trigger Link of the Model 2700 is connected to Trigger Link (either IN or OUT) of the Model 7002. Note that with the default trigger settings on the Model 7002, line #1 is an input and line #2 is an output. This complements the trigger lines on the Model 2700.

Figure 7-7
Trigger link connections



For this example, the Models 2700 and 7002 are configured as follows:

Model 2700

Factory defaults restored (accessed from SHIFT-SETUP)
External triggers (accessed from EX TRIG)
Buffer enabled and set to store 400 readings

Model 7002

Factory defaults restored
Scan list = 1!1-1!400,
Number of scans = 1
Channel spacing = TrigLink

The Model 2700 waits (with the asterisk annunciator lit) for an external trigger from the Model 7002.

Press STEP on the Model 7002 to take it out of idle and start the scan. The scanner's output pulse triggers the Model 2700 to take a reading, store it, and send a trigger pulse. The following explanation on operation is referenced to the operation model shown in Figure 7-8.

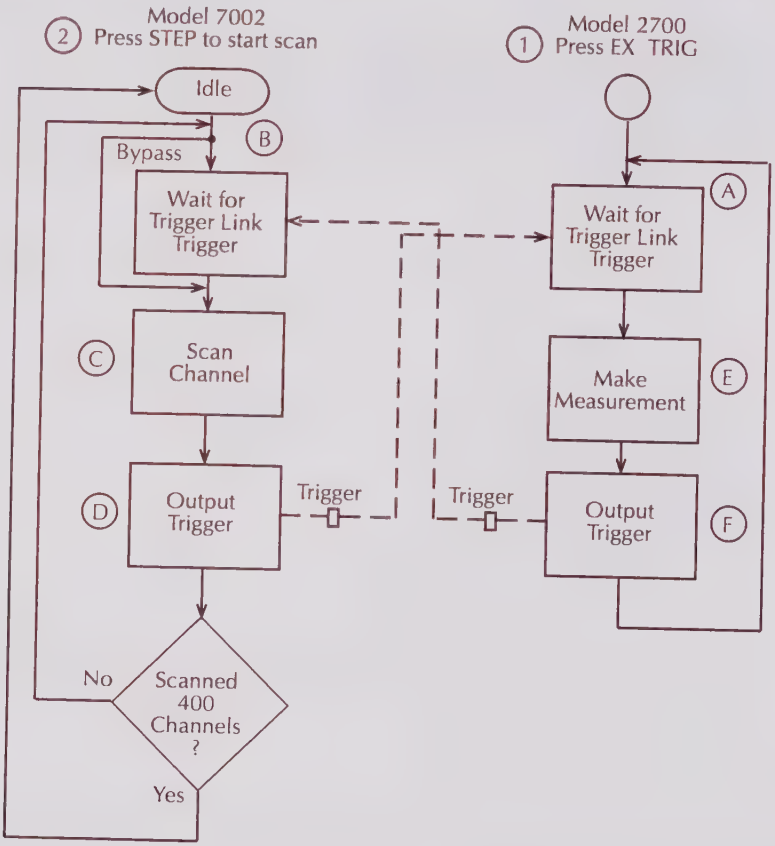


Figure 7-8
Operation model for triggering example

A. Pressing EX TRIG on the Model 2700 places it at point A in the flowchart, where it is waiting for an external trigger.

B. Pressing STEP on the Model 7002 takes it out of the idle state and places operation at point B in the flowchart.

C. For the first pass through the model, the scanner does not wait at point B for a trigger. Instead, it closes the first channel.

D. After the relay settles, the Model 7002 outputs a Channel Ready pulse. Since the instrument is programmed to scan 400 channels, operation loops back up to point B, where it waits for an input trigger.

E & F. Model 2700 operation is at point A waiting for a trigger. The output Channel Ready pulse from the Model 7002 triggers the Model 2700 to measure DUT #1 (point E). After the measurement is complete, the Model 2700 outputs a completion pulse (point F) and then loops back to point A, where it waits for another input trigger.

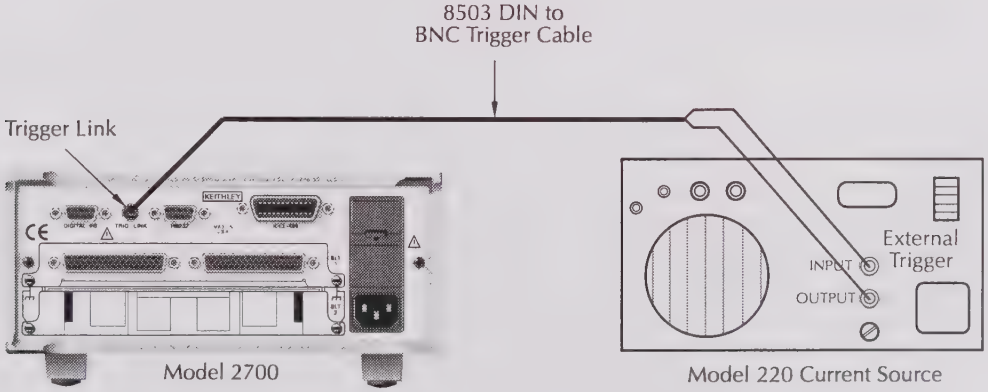
The trigger applied to the Model 7002 from the Model 2700 closes the next channel in the scan. This triggers the Model 2700 to measure the next DUT. The process continues until all 400 channels are scanned, measured and stored in the buffer.

External triggering with BNC connections

An adapter cable is available to connect the micro-DIN Trigger Link of the Model 2700 to instruments with BNC trigger connections. The Model 8503 DIN to BNC Trigger Cable has a micro-DIN connector at one end and two BNC connectors at the other end. The BNC cables are labeled VMC (trigger line 1) and EXT TRIG (trigger line 2).

Figure 7-9 shows how a Keithley Model 220 Current Source can be connected to the Trigger Link of the Model 2700 using the adapter cable. When used with the STEP mode of the Model 220, you can perform synchronized source-measure operations without the use of a computer. Whenever the Model 220 receives a trigger from the Model 2700, it will step to the next current source value.

Figure 7-9
DIN to BNC trigger cable

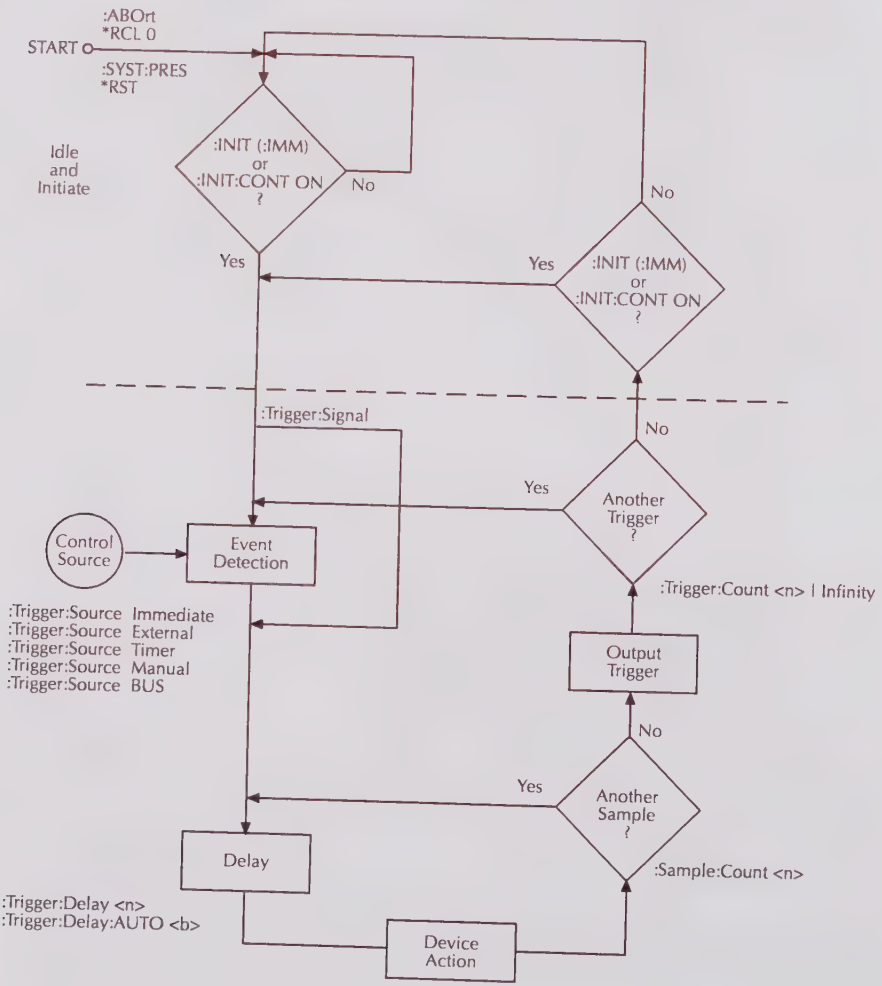


Remote programming — triggering

Trigger model (remote operation)

The following paragraphs describe how the Model 2700 operates for remote operation. The flowchart in Figure 7-10 summarizes operation over the bus. The flowchart is called the trigger model because operation is controlled by SCPI commands from the Trigger subsystem. Key SCPI commands are included in the trigger model.

Figure 7-10
Trigger model (remote operation)



Idle and initiate

The instrument is considered to be in the idle state whenever operation is at the top of the trigger model. As shown in Figure 7-10, initiation needs to be satisfied to take the instrument out of idle. While in the idle state, the instrument cannot perform any measure or step/scan operations.

The following commands will return operation to the top of the trigger model (idle) at the START point of the trigger model:

- :ABORt
- *RCL 0 to 3
- :SYSTem:PREset
- *RST

What happens next depends on the state of initiation. If continuous initiation is already enabled, the instrument will leave the idle state. SYSTem:PRESet enables continuous initiation. Therefore, operation will immediately leave the idle state when it is sent. The *RCL command will do the same if INITiation:CONTinuous ON is a user saved default. *RST disables continuous initiation. Therefore, the instrument will remain in the idle state.

Either of the following two initiate commands will take the instrument out of the idle state:

- :INITiate
- :INITiate:CONTinuous ON

NOTE *While in remote, pressing the LOCAL key restores continuous front panel operation.*

Trigger model operation

Once the instrument is taken out of idle, operation proceeds through the trigger model down to the device action. In general, the device action includes a measurement and, when stepping/scanning, closes the next channel.

Control Source — As shown in Figure 7-10, a control source is used to hold up operation until the programmed event occurs. The control source options are as follows:

- IMMediate — Event detection is immediately satisfied allowing operation to continue.
- MANual — Event detection is satisfied by pressing the TRIG key. The Model 2700 must be in LOCAL mode for it to respond to the TRIG key. Press the LOCAL key or send GTL over the bus to remove the instrument from the remote mode.
- TIMer — Event detection is immediately satisfied on the initial pass through the loop Each subsequent detection is satisfied when the programmed timer interval (0 to 999999.999 sec) elapses. The timer source is only available during scan operation. The timer resets to its initial state when the instrument goes into the normal mode of operation or into the idle state.
- EXTernal — Event detection is satisfied when an input trigger via the TRIG LINK connector is received by the Model 2700.
- BUS — Event detection is satisfied when a bus trigger (GET or *TRG) is received by the Model 2700.

Delay and Device Action — These blocks of the trigger model operate the same for both front panel and GPIB operation. See the front panel "Trigger Model" (located at the beginning of this section) for operating information on these trigger model blocks. Also see "Reading hold (autosettle)" for details on Hold.

Counters — Programmable counters are used to repeat operations within the trigger model. For example, if performing a 10-channel scan, the sample counter would be set to 10. Operation will continue until all 10 channels are scanned and measured. If you wanted to repeat the scan three times, you would set the trigger counter to three.

For a sample count value >1, the sample readings will automatically be stored in the buffer. For example, with sample count set to 5, the five measured readings will be stored in the buffer. If the trigger model is configured to repeat the sample readings (i.e. trigger count = 2), those five new readings will overwrite the original five readings in the buffer.

Output Trigger — The Model 2700 will send one or more output triggers. The output trigger is applied to the Trigger Link connector on the rear panel. It can be used to trigger an external instrument to perform an operation.

The trigger model can be configured to output a trigger after the completion of a series of measurements, or after every measurement. For example, with the sample counter set to 10 and the trigger counter set to one, a trigger will be sent after the 10 measurements are performed. If instead, the trigger counter is set to 10 and the sample counter is set to 1, a trigger will be sent after each measurement.

Triggering commands

Commands for triggering are summarized in Table 7-2.

Table 7-2
SCPI commands — triggering

Commands	Description	Default	Ref
:ABORt	Reset trigger system.		A
:INITiate[:IMMediate]	Initiate one trigger cycle.		B
:INITiate:CONTinuous <b>	Enable/disable continuous initiation; <b> = ON or OFF.	Note 1	C
:FETch?	Request the last reading(s).		D
:READ?	Perform an ABORt, INITiate and a FETch?		E
:TRIGger:SOURce <name>	Select control source; IMMediate, TIMer, MANual, BUS, or EXTernal.	IMM	F
:TRIGger:TIMer <n>	Set timer interval; 0 to 999999.999 (sec).	0.1	
:TRIGger:COUNt <NRf>	Set trigger count; 1 to 9999 or INFinity.	Note 2	
:TRIGger:DELay <n>	Set delay; 0 to 999999.999 (sec).	0	

Table 7-2 (Continued)
SCPI commands — triggering

Commands	Description	Default	Ref
:TRIGger:DELay:AUTO <b>	Enable or disable auto delay.		G
:TRIGger:SIGNal	Loop around control source.		H
:SAMPle :COUNt <NRf>	Set sample count; 1 to 55000.	1	I
[:SENSe[1]	Optional root command for HOLD commands.		J
:HOLD:WINDow <NRf>	Set Hold window in %; <NRf> = 0.01 to 20.	1	
:HOLD:COUNt <NRf>	Set Hold count; <NRf> = 2 to 100.	5	
:HOLD:STATe <b>	Enable or disable Hold.	OFF	
:SYSTem:BEEPer:STATe <b>	Enable or disable the beeper.	ON	
*RST	Restore *RST defaults (see "Default" column of this table). Places 2700 in the idle state.		

Notes:
1. Defaults for continuous initiation:
   SYSTem:PRESet enables continuous initiation.
   *RST disables continuous initiation.
2. Defaults for trigger count:
   SYSTem:PRESet sets the count to INF (infinity).
   *RST sets the count to 1.

Reference

A. ABORt
With continuous initiation disabled, the 2700 goes into the idle state. With continuous initiation enabled, operation continues at the top of the trigger model.

B. INITiate
Whenever the instrument is operating within the trigger model, sending this command causes an error and will be ignored.

C. INITiate:CONTinuous <b>
With continuous initiation enabled, you cannot use the READ? command or set sample count (SAMPle:COUNt) greater than one.

D. FETch?
See Section 12 for details on this Signal Oriented Measurement Command.

E. READ?
Use this one query command to perform the tasks of the three commands. See Section 12 for details on this Signal Oriented Measurement Command.

F. TRIGger:SOURce <name>
With the timer control source selected, use the TRIGger:TIMer command to set the interval.

G. DELay:AUTO <b>
The auto delay times are listed in Table 7-1. Disabling auto delay sets the delay time to 0.

H. TRIGger:SIGNal
Send this action command to bypass the control source when you do not wish to wait for the programmed event to occur. The instrument must be waiting at the control source for the event when this command is sent. Otherwise, an error occurs and the command is ignored.

I. SAMPle:COUNt
A sample count >1 specifies how many readings will automatically be stored in the buffer. However, with continuous initiation enabled, you cannot set the sample count greater than one.

J. [SENSe[1]]:HOLD commands
Hold cannot be set when the scanner is enabled (ROUTe:SCAN:LSEL INT). Sending a hold command will result in a settings conflict error (-221).

Programming example

The following program fragment triggers (and stores in the buffer) 10 readings. Note that in order to send the readings to the computer, you must address the Model 2700 to talk after sending READ?.

```
*RST                          ' Restore *RST defaults.
TRAC:CLE                      ' Clear buffer.
TRIG:DEL 0.5                  ' Set delay for 0.5sec.
SAMP:COUN 10                  ' Set sample count to 10.
READ?                         ' Trigger, store and request readings.
```

8
Limits and Digital I/O

- **Limits** — Explains how to perform limit tests on measured readings.
- **Digital I/O** — Covers the digital I/O port. Explains how the five digital outputs respond to the results of limit tests.
- **Remote programming** — Summarizes the commands to perform limit tests and control the digital I/O port.
- **Application - sorting resistors** — Provides an application to test the tolerances of 100W resistors. Provides the digital output response to the various pass/fail combinations of the limit tests.

Limits

NOTE *Limits cannot be used with the CONT function.*

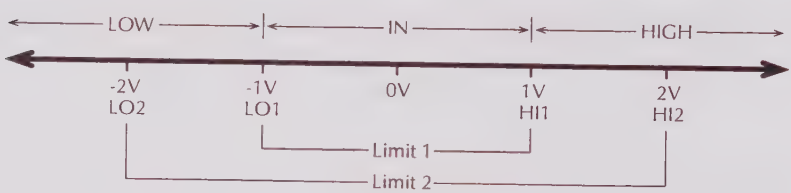
When using limits, you can set and control the values that determine the HIGH/IN/LOW status of subsequent measurements. The limit test is performed on the result of an enabled Rel, Math, Ratio, or Channel Average operation.

There are two sets of limits. Limit 1 uses high and low limits (HI1 and LO1), as does Limit 2 (HI2 and LO2). The HIGH/IN/LOW status indication applies to the first limit (limit 1 or limit 2) that fails. Figure 8-1 illustrates the following limits which are the factory defaults:

Limit 1: HI1 = +1V and LO1 = -1V
Limit 2: HI2 = +2V and LO2 = -2V

Keep in mind that a limit value for Limit 2 does not have to exceed the Limit 1 value. For example, Limit 2 can be set to ±1V and Limit 1 can be set to ±2V. In this case, Limit 2 will fail before Limit 1.

Figure 8-1
Default limits



When a reading is within both limits, the message "IN" will be displayed. When the reading is high or low, the HIGH or LOW annunciator turns on, and the number "1" or "2" will replace the "IN" message. A "1" indicates that Limit 1 has failed, while "2" indicates that Limit 2 has failed. However, if the reading is outside both limits, the number "1" will be displayed.

For the limits shown in Figure 8-1, a reading of +1.5V is outside Limit 1, but inside Limit 2. The HIGH annunciator will turn on and display the number "1." For a reading of +2.5V, which is outside both Limit 1 and Limit 2, the same status indication (HIGH, "1") will be displayed since Limit 1 takes precedence.

NOTE *When a switching module channel is closed, the message "I" replaces the message "IN" to indicate that the reading is inside both Limit 1 and Limit 2.*

For limit test readings that get stored in the buffer, the limits status indicators are displayed for each recalled reading.

When a limit test reading is returned using remote programming, limit test status can be included with the reading. See "Format commands" in Section 13 for details.

Beeper — A beeper is also available for limit testing. There are three beeper options; NEVER, OUTSIDE, and INSIDE. These options are explained as follows:

NEVER — With this option, the beeper is disabled.

OUTSIDE — With this option, the beeper sounds when the reading is outside (HIGH or LOW) of Limit 1 or Limit 2. Again referring to Figure 8-1, a +1.5V reading is outside (HIGH) limit 1, and the beeper will sound.

INSIDE — With this option, the beeper will sound when the reading is inside Limit 1 and/or Limit 2. If the reading is inside Limit 1, the beeper will sound raspy. If the reading is outside Limit 1, but inside Limit 2, the beeper will sound at a lower pitch. The beeper will not sound for readings outside both limits. For the limits shown in Figure 8-1, a 0.5V reading will sound the beeper at its normal pitch, a 1.5V reading will sound the beeper at a lower pitch, and for a 2.5V reading, the beeper will not sound.

Tips to use Limit 2 test

Limits 1 < Limits 2 — When the set limits for Limit 1 are less than the limits for Limit 2 (i.e., Figure 8-1), use the INSIDE beeper. As previously explained, when the reading is between Limit 1 and Limit 2, the beeper will sound raspy.

Limits 1 > Limits 2 — When the set limits for Limit 1 are greater than the limits for Limit 2, use the OUTSIDE beeper. When the reading is between Limit 1 and Limit 2, the beeper will sound raspy.

Scanning

When a simple scan is configured, the present limit values and state will apply to all channels in the scan. When an advanced scan is configured, each channel can have its own unique limits configuration. Details to configure and run a scan are provided in Section 6.

For remote programming, the <clist> parameter is used to configure channels for a scan.

Basic limits operation

The limits configuration is the same for all functions. For example, if a reading limit is set to 1, that will equate to 1V for a voltage function, 1A for a current function, and 1Ω for an ohms function.

Setting limits

1. Press SHIFT and then LIMITS to display the high limit for Limit 1 (HI1).
2. Use ◀, ▶, ▲, and ▼ to key in the HI1 limit and press ENTER.
   When editing a reading, use the range designator (▲, K, or M) as a multiplier. With the cursor on the range designator, each press of ▲ or ▼ will increase or decrease the reading by a factor of 10.
3. Key in the low limit for Limit 1 (LO1), and press ENTER.

4. Key in the high limit for Limit 2 (HI2), and press ENTER.
5. Key in the low limit for Limit 2 (LO2), and press ENTER. The instrument will return the normal measurement state.

Beeper settings

The beeper is configured from the OUTPUT menu (shown in Table 8-1) as follows:

1. Press SHIFT and then OUTPUT.
2. Use the ▲ or ▼ key to display the present beeper (BEEP) setting; NEVER, INSIDE, or OUTSIDE.
3. Press ▶ to position the cursor on the present beeper setting, use the ▲ or ▼ key to display the desired setting, and press ENTER. The instrument will return to the normal measurement state.

NOTE *Remote programming cannot be used to set the beeper. It can only be set from the front panel.*

Enabling/disabling limits

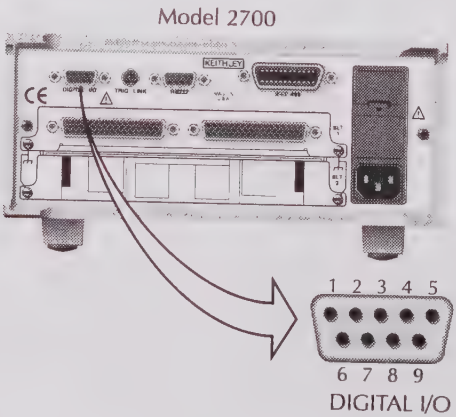
Press SHIFT and then ON/OFF to display the present state (off or on) of limits. To enable limits, use the ▲ or ▼ key to display "LIMITS: ON" and press ENTER.

To disable limits, again press SHIFT and then ON/OFF, select "LIMITS: OFF", and press ENTER.

Digital I/O

Model 2700's Digital I/O port is accessed at a male DB-9 connector located on the rear panel. The connector location and pin designations are shown in Figure 8-2.

Figure 8-2
Digital I/O port



1 = Digital Output # 1 (low limit 1)
2 = Digital Output # 2 (high limit 1)
3 = Digital Output # 3 (low limit 2)
4 = Digital Output # 4 (high limit 2)
5 = Digital Output # 5 (master limit)
6 = Ext Trig (input)
7 = Diode Clamp
8 = Hardware Interlock (input)
9 = Digital (chassis) Ground

Digital input (trigger link input)

When enabled, the Trigger In (pin 6) and Digital Ground (pin 9) can be used as the trigger link input for external triggering. Pin 6 is physically connected to the input line (pin 2) of the TRIG LINK connector.

Pin 8 of the digital I/O is used to enable or disable Trigger In. Trigger In is enabled by leaving pin 8 open, or pulling it high (+5V). Trigger In is disabled by setting pin 8 low (0V).

NOTE External triggering is covered in Section 7.

Digital outputs

The digital I/O port has five digital outputs. Each digital output can be used as a sink to control inductive devices (i.e., relays), or as a source to provide input to external logic (TTL or CMOS) circuitry. The simplified schematic for the digital outputs are shown in Figure 8-3. Note that this illustration shows the schematic for one digital output. All four digital output circuits are identical.

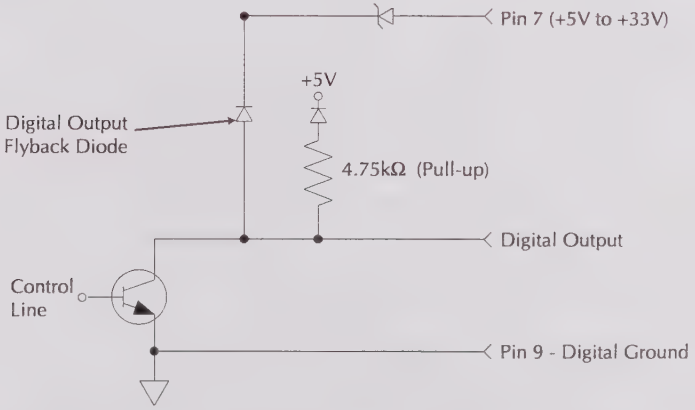


Figure 8-3
Digital I/O port simplified schematic

The five digital output lines (pins 1 through 5) are controlled by limit operations. Each of these five outputs correspond to the following limit operations:

Digital Output 1 - Low Limit 1 (LO1)
Digital Output 2 - High Limit 1 (HI1)
Digital Output 3 - Low Limit (LO2)
Digital Output 4 - High Limit 2 (HI2)
Digital Output 5 - Master Limit (logical OR of the four limits)

When a limit (LO1, HI2, LO2, HL2) is reached, the digital output line for that limit will be pulled high or low. When a reading is within the limit, the output line is released. Digital output 5 is the logical OR of the four limits. Therefore, if any of the four limits are reached or exceeded, output 5 will be pulled high or low.

Logic sense

The selected logic sense (active high or active low) determines if an output is pulled high or low when the limit is reached. If logic sense is set high, the output line will be pulled high when the reading reaches or exceeds the limit. If logic sense is set low, the output line will be pulled low to 0V when the reading reaches or exceeds the limit.

Pulse option

Pulse option is available for the digital outputs. When enabled, an output line will pulse high or low (depending on the logic sense setting) for each reading that reaches or exceeds the limit. The factory default time duration for the pulse is 2ms (maximum), but can be set from 0.001 to 999999.999 seconds using remote programming. Pulse time cannot be set from the front panel.

NOTE *The commands to set pulse time and enable/disable pulse output are listed in Table 8-2. See "Digital output commands" in the table.*

The pulse time does not affect measurement speed. If a subsequent in-limit reading occurs while the output line is being pulsed, the line will be released immediately (pulse terminated).

Master limit latch

The master limit line is pulled high or low when one or more of the other four limits are reached or exceeded. The master limit line can be programmed to release when a reading is inside all four limits, or the master limit can be latched when a failure occurs. When latched, the master limit line will not release until operation within the trigger model returns to and passes the control source (see Section 7 for details on triggering).

When scanning, the latched master limit line will not release until the scan is finished and another scan is started. For example, if after testing a resistor network the master limit line did set, then the network has passed all tests.

Sink mode — controlling external devices

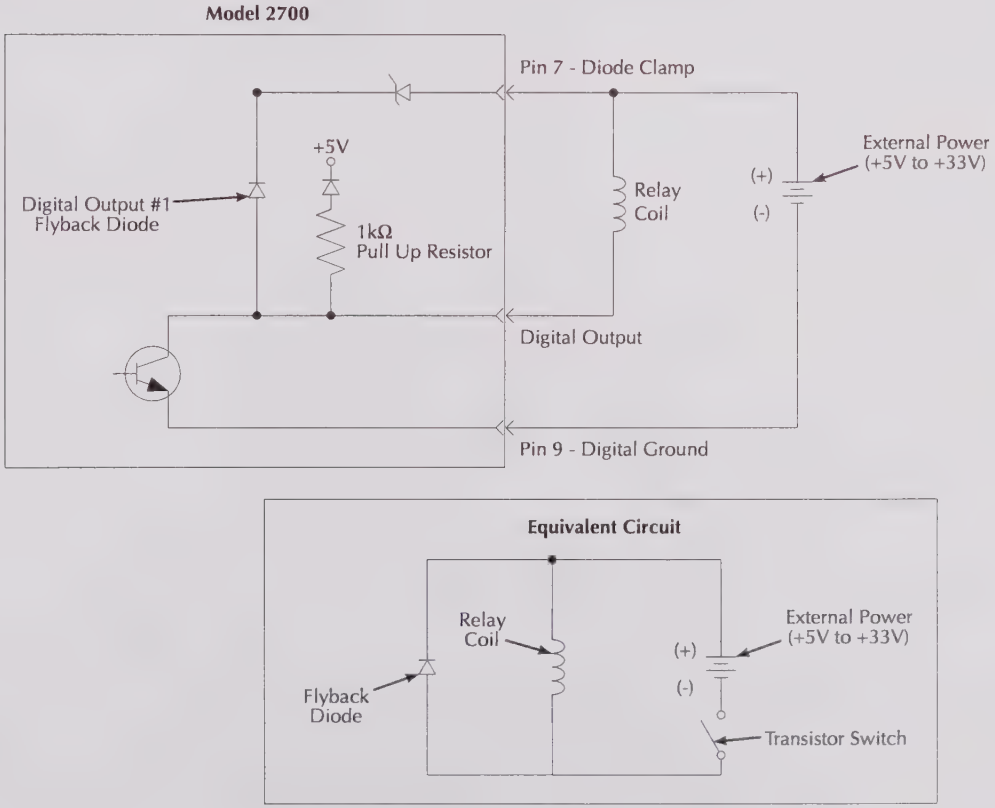
Each output can be operated from an external supply (voltage range from +5V to +33V applied through the external device being driven). The high current sink capacity of the output driver allows direct control of relays, solenoids, and lamps (no additional circuitry needed).

As shown in Figure 8-3, each of the digital, open-collector outputs includes a built-in pull up resistor connected to +5V. The output transistor is capable of sinking 250mA from voltages up to +33V. Each output channel contains a fly-back diode for protection when switching inductive loads (such as a low power solenoid or relay coils). To use these fly-back diodes, connect the external supply voltage to pin 7 of the digital I/O port. Make sure the external supply voltage is between +5V and +33V and the current required by the device does not exceed 250mA.

CAUTION **On pin 7, do not exceed +33V. For the output lines, do not exceed the maximum sink current. The maximum sink current for an output line is 250mA. Exceeding these limits may cause damage to the instrument that is not covered by the warranty.**

An externally powered relay connected to the digital output port is shown in Figure 8-4. Other externally powered devices can be similarly connected by replacing the relay with the device. When the output line is pulled low (0V), the output transistor sinks current through the external device. In the high state, the output transistor is off (transistor switch open). This interrupts current flow through the external device.

Figure 8-4
Controlling externally powered relays



Source mode — logic control

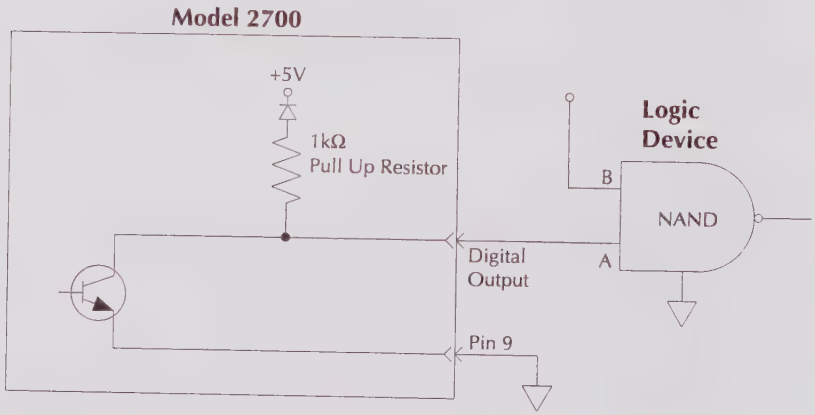
The digital outputs can be used as logic inputs to active TTL, low-power TTL, or CMOS inputs. For this mode of operation, the output lines can source up to 200µA.

CAUTION **Each output line can source up to 200µA. Exceeding 200µA may cause damage to Model 2700 that is not covered by the warranty.**

Figure 8-5 shows how to connect a logic device to one of the output lines. When the output line is pulled high, the transistor will turn off (transistor switch open) to provide a reliable logic high output (>3.75V). When the output line goes low, the transistor turns on (transistor switch closed) to route current to digital ground. As a result, a low logic output (0V) is provided at the output.

If the second input (B) of the NAND gate is connected to another output line of the port, the output of the NAND gate will go to logic 0 when both digital outputs are set high.

Figure 8-5
NAND gate control



Setting digital output

The OUTPUT menu (shown in Table 8-1) is used to control and configure digital outputs. Menu items for the digital output include:

- DOUTPUT — Use to enable (ON) or disable (OFF) the digital outputs.
- PULSE — Use to enable (YES) or disable (NO) the pulse option for the digital outputs.

NOTE *The factory default pulse time is 2ms maximum. Using remote programming, pulse time can be set from 0.001 to 999999.999 sec. It cannot be set from the front panel.*

- LSENSE — Use to select the logic sense; active HIGH or active LOW. With active high selected, an output will be at approximately +5V when a reading is at or exceeds the limit. Conversely, with active low selected, an output will be at 0V when a reading reaches or exceeds the limit.

- MASTR LATCH — Use to enable (Y) or disable (N) the master limit latch. When enabled, the master limit remains latched when a reading limit is reached or exceeded. When disabled, the master limit line releases immediately when the reading is inside all four limits.

Table 8-1
OUTPUT menu

Menu item	Setting	Description
DOUTPUT	ON or OFF	Enable/disable digital outputs.
PULSE	YES or NO	Enable/disable digital pulse output.
LSENSE	HIGH or LOW	Select logic sense.
BEEP	NEVER, INSIDE, or OUTSIDE	Set beeper for limits (see "Limits" for details).
MASTR LATCH	Y or N	Enable/disable master limit latch.

Perform the following steps to enable and configure digital outputs:

1. Press SHIFT and then OUTPUT.
2. If the digital output is already on (DOUTPUT: ON), proceed to step 3. Otherwise, press ▶ to move the cursor to the right, press ▲ or ▼ key to display "ON," and press ENTER.
3. Use the ▼ key to display the master limit latch (MASTR LATCH) setting; N (no) or Y (yes).
4. If you want to retain the present master limit setting, proceed to step 5. Otherwise, press ▶ to move the cursor to the right, press ▲ or ▼ key to display "Y" or "N," and press ENTER.
5. Use the ▼ key to display the present logic sense (LSENSE) setting; HIGH or LOW.
6. If you want to retain the present logic sense setting, proceed to step 7. Otherwise, press ▶ to move the cursor to the right, press ▲ or ▼ key to display "HIGH" or "LOW," and press ENTER.
7. Use the ▼ key to display the present PULSE mode setting; NO or YES.
8. To retain the present pulse mode setting, press ENTER. Otherwise, press ▶ to move the cursor to the right, press ▲ or ▼ key to display "NO" or "YES," and press ENTER.

Scanning

While limits can be configured on a per scan channel basis, the digital output configuration cannot. Therefore, for all scan channels that are set to use limits, the digital output will function according to how the Model 2700 is set up when the scan is run.

Remote programing — limits and digital output

Limits and digital output commands

The limits and digital output commands are provided in Table 8-2.

Table 8-2
Limits and digital I/O commands

Commands*	Description	Def	Ref
Limit 1 commands:			
:CALCulate3:LIMit1:UPPer <NRf> [, <clist>]	Set HI1 limit; <NRf> = -4294967295 to +4294967295	1	
:CALCulate3:LIMit1:LOWer <NRf> [, <clist>]	Set LO1 limit; <NRf> = -4294967295 to +4294967295	-1	
:CALCulate3:LIMit1:STATe <b> [, <clist>]	Enable/disable Limit 1 test; <b> = ON or OFF.		A
:CALCulate3:LIMit1:FAIL?	Query test result; 0 = pass (in), 1 = fail (high or low).		B
:CALCulate3:LIMit1:CLEar	Clear fail indication.		C
:CALCulate3:LIMit1:CLEar:AUTO <b>	Enable/disable auto clear; <b> = ON or OFF.	ON	C
Limit 2 commands;			
:CALCulate3:LIMit2:UPPer <NRf> [, <clist>]	Set HI2 limit; <NRf> = -4294967295 to +4294967295	2	
:CALCulate3:LIMit2:LOWer <NRf> [, <clist>]	Set LO2 limit; <NRf> = -4294967295 to +4294967295	-2	
:CALCulate3:LIMit2:STATe <b> [, <clist>]	Enable/disable Limit 1 test; <b> = ON or OFF.		A
:CALCulate3:LIMit2:FAIL?	Query test result; 0 = pass (in), 1 = fail (high or low).		B
:CALCulate3:LIMit2:CLEar	Clear fail indication.		C
:CALCulate3:LIMit2:CLEar:AUTO <b>	Enable/disable auto clear; <b> = ON or OFF.	ON	C
Digital output commands:			
:CALCulate3:OUTPut:LSENse <name>	Set logic sense; <name> = AHIGh or ALOW.	AHIGh	
:CALCulate3:OUTPut:[STATe] <b>	Enable/disable digital outputs; <b> = ON or OFF.	OFF	
:CALCulate3:OUTPut:PULSe:TIMe <NRf>	Set output pulse time in secs; <NRf> = 0.001 to 999999.999.	0.002	
:CALCulate3:OUTPut:PULSe[:STATe] <b>	Enable/disable pulse output; <b> = ON or OFF.	OFF	
:CALCulate3:MLIMit:LATCHed <b>	Enable/disable master limit latch.	OFF	

Channel list parameter:
<clist> = (@SCH)
where: S = Mainframe slot number (1 or 2)
CH = Switching module channel number (must be 2 digits)
Examples: (@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

*The <clist> parameter is used to configure one or more channels for a scan.

Reference

A. :CALCulate3:LIMit1:STATe <b> [, <clist>]
:CALCulate3:LIMit2:STATe <b> [, <clist>]

Unlike front panel operation, Limit 1 and Limit 2 can be controlled (on/off) separately for remote programming. The front panel limit indicators are affected as follows:

Limit 1 enabled — The front panel HIGH/IN/LOW indicators work the same as they do for front panel operation.

Limit 1 disabled and Limit 2 enabled — The status indicators pertain to Limit 2. When the reading is within Limit 2, the message "I2" is displayed. When the reading reaches or exceeds the high or low limit, the HIGH or LOW annunciator will turn on, and the number "2" will be displayed.

NOTE *When limits are disabled from the front panel, both Limit 1 and Limit 2 disable for remote operation.*

B. :CALCulate3:LIMit1:FAIL?
:CALCulate3:LIMit2:FAIL?

These commands are used to query the results of Limit 1 and Limit 2:

0 = Passing (reading within the high and low limits)
1 = Failing (reading has reached or exceeded the high or low limit)

The "1" response message does not tell you which limit (high or low) has been reached. To determine which limit has failed, you will have to read the measurement event register (see Section 10).

C. :CALCulate3:LIMit1:CLEar
:CALCulate3:LIMit1:CLEar:AUTO <b>
:CALCulate3:LIMit2:CLEar
:CALCulate3:LIMit2:CLEar:AUTO <b>

These commands are used to clear the fail ("1") indications for Limit 1 and Limit 2. If auto clear is enabled for a limit, the fail indication clears when instrument operation enters the idle state. With auto clear disabled, the fail indication will remain until it is cleared by the :CLEar command.

Limits and digital outputs programming example

The following command sequence configures the Model 2700 to perform Limit 1 test on a DCV reading. If the 100mV limit is reached, digital output # 2 will be pulled low. If the -100mV limit is reached, digital output #1 will be pulled low.

```
*RST                                    ' One-shot measurement mode (DCV).
CALC3:LIM1:UPP 0.1                      ' Set HI1 limit to 100mV.
CALC3:LIM1:LOW -0.1                     ' Set LO1 limit to -100mV.
CALC3:LIM1:STAT ON                      ' Enable Limit 1.
CALC3:LSEN ALOW                         ' Set logic sense to active low.
CALC3:OUTP ON                           ' Enable digital outputs.
READ?                                   ' Trigger and request reading.
CALC3:LIM1:FAIL?                        ' Request result of limit 1 test.
```

Application — sorting resistors

For this application, the idea is to sort a batch of 100Ω resistors into three bins. Bin 1 is for resistors that are within 1% of the nominal value. Bin 2 is for resistors that exceed 1% tolerance, but are within 5%. Bin 3 is for resistors that exceed 5% tolerance.

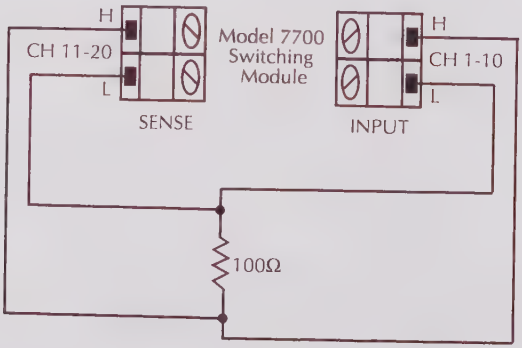
The digital outputs of the Model 2700 can be used to further automate the test system by controlling a compatible component handler to perform the binning operations.

Limits

Limit testing is used to test resistor tolerances. Figure 8-6 shows a basic setup using 4-wire offset compensated ohms to test 100Ω resistors.

Figure 8-6
Setup to test 100Ω resistors

A) Front panel inputs



B) Model 7700

Limit 1 will be used to test for the 1% tolerance and Limit 2 will be used to test for the 5% tolerance.

The resistance values for the 1% and 5% tolerances are calculated as follows:

$$R_{1\%} = 100\Omega \times 1\% = 100\Omega \times 0.01 = 1\Omega$$

$$R_{5\%} = 100\Omega \times 5\% = 100\Omega \times 0.05 = 5\Omega$$

The high and low limits are then calculated as follows:

$$\text{HI Limit 1} = 100\Omega + R_{1\%} = 100\Omega + 1\Omega = 101\Omega$$

$$\text{LO Limit 1} = 100\Omega - R_{1\%} = 100\Omega - 1\Omega = 99\Omega$$

$$\text{HI Limit 2} = 100\Omega + R_{5\%} = 100\Omega + 5\Omega = 105\Omega$$

$$\text{LO Limit 2} = 100\Omega - R_{5\%} = 100\Omega - 5\Omega = 95\Omega$$

The limits are illustrated Figure 8-7.

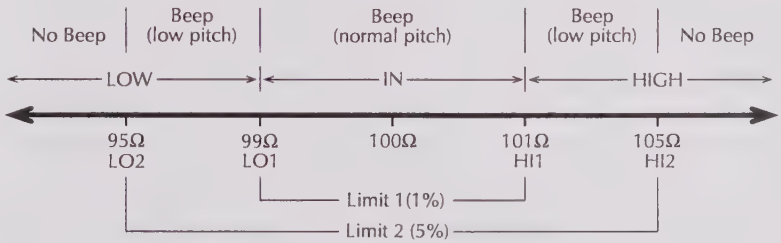


Figure 8-7
Limits to sort 100Ω resistors (1%, 5%, and >5%)

Front Panel Operation — For front panel operation, the INSIDE beeper mode must be used. A normal pitch beep and the message "IN" indicates that the resistor is within the 1% tolerance limit (see Figure 8-7). This 1% resistor belongs in Bin 1. A raspy beep and the "1" message indicates that the resistor is >1% tolerance but <5% tolerance. This 5% resistor belongs in Bin 2. For resistors >5%, no beep will sound. Place these resistors in Bin 3.

Remote Operation — For remote operation, make sure both Limit 1 and Limit 2 are enabled. The following table evaluates the three possible pass/fail combinations for this example.

Limit 1 Result	Limit 2 Result	Resistor Tolerance	Bin Assignment
Pass	Pass	1%	1
Fail	Pass	5%	2
Fail	Fail	>5%	3

Keep in mind that a fail condition must be reset before testing the next resistor. Fail can be reset manually or automatically (see CLEar command in Table 8-2).

Digital outputs

With the digital outputs of the Model 2700 enabled, the digital outputs will respond as follows for each resistor reading:

LO Limit 2	LO Limit 1	HI Limit 1	HI Limit 2	Resistor Tolerance	Bin	Affected Outputs*
Pass	Pass	Pass	Pass	1%	1	None
Pass	Fail	Pass	Pass	5%	2	#1 and #5
Pass	Pass	Fail	Pass	5%	2	#2 and #5
Fail	Fail	Pass	Pass	>5%	3	#1, #3 and #5
Pass	Pass	Fail	Fail	>5%	3	#2, #4 and #5

*Affected outputs are pulled (or pulsed) high or low when a limit test fails.

9
Remote Operations

- **Operation enhancements** — Summarizes some of the more important operations that can be only be performed using remote operation.
- **GPIB setup** — Covers GPIB bus standards, selecting the GPIB, primary address selection, and bus connections.
- **General bus commands** — Describes general bus commands used for fundamental GPIB control.
- **Front panel GPIB operation** — Summarizes GPIB error messages, status indicators, and using the LOCAL key.
- **Programming syntax** — Describes the basic programming syntax for both common and SCPI commands.
- **RS-232 interface operation** — Outlines use of the RS-232 interface to control the Model 2700.

Operation enhancements

There are some operations you can do over the IEEE-488 bus and RS-232 interface that you cannot do from the front panel. The more important ones are summarized below.

Pseudocards

Using remote operation, you can assign a pseudocard to an empty switching module slot. With a pseudocard "installed," the Model 2700 will operate as if the switching module is installed in the Model 2700. This feature allows you to configure your system without having the actual switching module installed in the unit. There is a pseudocard for every Keithley Model 7700 series switching module.

A single SCPI command (:PCARd or :PCARd2) is used to "install" a pseudocard in an empty switching module slot. Details are provided in Section 1.

A pseudocard cannot be "installed" from the front panel. However, once it is "installed" you can take the Model 2700 out of remote and use the front panel. When the instrument is turned off, the pseudocard will be lost (uninstalled).

Autozero

Autozero is part of the normal measurement process to assure stable, accurate measurements. Autozero can be disabled to increase measurement speed. However, the readings will eventually become inaccurate over time and temperature changes.

Autozero can only be disabled using remote programming. It cannot be disabled from the front panel. Autozero is covered in Section 2.

dB calculation

Using remote programming, you can select the dB calculation for DC or AC voltage. The dB calculation makes it possible to compress a large range of measurements into a much smaller scope. See Section 4 to select and configure the dB calculation.

You cannot select dB from the front panel. However, once it is selected you can take the Model 2700 out of remote and use the front panel. When the instrument is reset to default conditions (or turned off), dB will be lost.

Separate function setups

A few settings from the front panel are global. That is, the setting on one function also applies to the other functions. For example, if you set DCV for 3½ digits, all the other functions will also be set to 3½ digits. Using remote programming, each function can have its own unique setup. For example, DCV can be set to 3½ digits, ACI can be set to 4½ digits and DCI can be set to 5½ digits.

Global settings from the front panel that can be set separately using remote programming include digits, rate and filter configuration (except on/off, which can be set separately).

NOTE *Do not confuse function setups with scan channel setups. For scan channels, separate settings for digits, rate and filter configuration can be set from either the front panel or remote programming. See Section 6 for details on scan channel setup.*

DCV input divider

Using remote programming, you can enable the DCV input divider for the 100mV, 1V, and 10V ranges. When enabled, the input resistance for these DCV ranges are reduced to 10MΩ. See Section 2 for details on the DCV input divider.

Mult-close/open operation

For normal operation, when one switching module channel is closed, any other closed channel opens. With the use of the ROUTe:MULTiple commands, you gain independent control of all switching module channels, including the relays that connect the input signal to the DMM. See "Model 7700 switching module" in Section 2 for details.

GPIB setup

The following provides information about GPIB standards, selecting the GPIB, setting the primary address and bus connections.

GPIB standards

The GPIB is the IEEE-488 instrumentation data bus with hardware and programming standards originally adopted by the IEEE (Institute of Electrical and Electronic Engineers) in 1975. The Model 2700 conforms to these standards:

- IEEE-488.1-1987
- IEEE-488.2-1992

The above standards define a syntax for sending data to and from instruments, how an instrument interprets this data, what registers should exist to record the state of the instrument, and a group of common commands. The Model 2700 also conforms to this standard:

- SCPI 1996.0 (Standard Commands for Programmable Instruments)

This standard defines a command language protocol. It goes one step farther than IEEE-488.2-1992 and defines a standard set of commands to control every programmable aspect of an instrument.

Selecting GPIB and setting primary address

The Model 2700 is shipped from the factory with the GPIB selected and the primary address set to 16. You can set the address to a value from 0 to 30, but do not assign the same address to another device or to a controller that is on the same GPIB bus (controller addresses are usually 0 or 21).

Perform the following steps to select the GPIB and set the primary address:

1. Press the SHIFT key and then the GPIB key. The GPIB ON or GPIB OFF message will be displayed.
2. If the GPIB is already ON, press ENTER and proceed to step 3. Otherwise, press the ▶ key to place the cursor on OFF, press the ▲ or ▼ key to display the ON state, and then press ENTER.

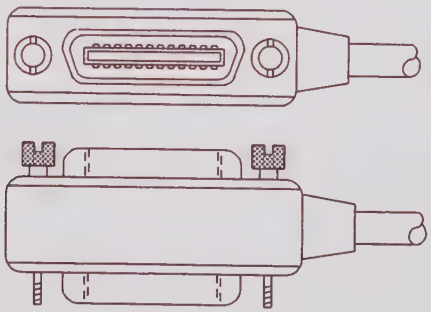
NOTE *Enabling (ON) the GPIB disables (OFF) the RS-232 interface. Disabling the GPIB enables the RS-232.*

3. To retain the presently displayed address (ADDR) value, press ENTER. Otherwise, press the ▶ key to place the cursor on the address value, use the ◀, ▶, ▲, and ▼ keys to display the desired address value, and then press ENTER.

GPIB connections

To connect the Model 2700 to the GPIB bus, use a cable equipped with standard IEEE-488 connectors as shown in Figure 9-1.

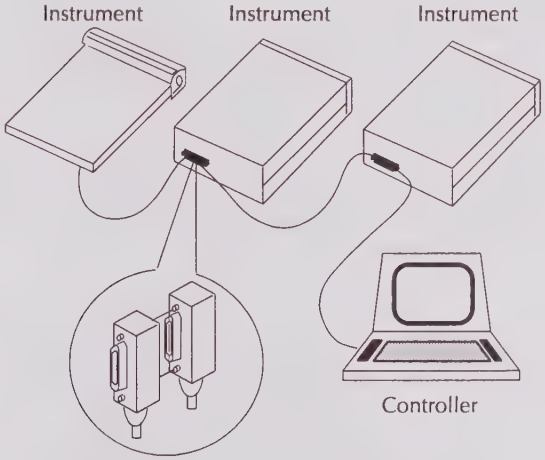
Figure 9-1
IEEE-488 connector



To allow many parallel connections to one instrument, stack the connectors. Two screws are located on each connector to ensure that connections remain secure. Present standards call for metric threads, which are identified with dark-colored screws. Earlier versions have different screws, which are silver-colored. Do not use these types of connectors on the Model 2700; it is designed for metric threads.

Figure 9-2 shows a typical connecting scheme for a multi-unit test system.

Figure 9-2
IEEE-488 connections



To avoid possible mechanical damage, stack no more than three connectors on any one unit.

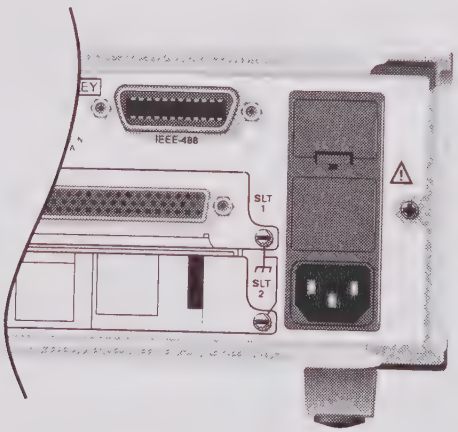
NOTE *To minimize interference caused by electromagnetic radiation, use only shielded IEEE-488 cables. Available shielded cables from Keithley are Models 7007-1 and 7007-2.*

To connect the Model 2700 to the IEEE-488 bus, follow these steps:

1. Line up the cable connector with the connector located on the rear panel. The connector is designed so it will fit only one way. Figure 9-3 shows the location of the IEEE-488 connector.
2. Tighten the screws securely, making sure not to overtighten them.
3. Connect any additional connectors from other instruments as required for your application.
4. Make sure the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. See your controller's instruction manual for information about properly connecting to the IEEE-488 bus.

NOTE *You can only have 15 devices connected to a IEEE-488 bus, including the controller. The maximum cable length is either 20 meters or two meters multiplied by the number of devices, whichever is less. Not observing these limits may cause erratic bus operation.*

Figure 9-3
IEEE-488 connector location



General bus commands

General commands are those commands, such as DCL, that have the same general meaning regardless of the instrument. Table 9-1 lists the general bus commands.

Table 9-1
General bus commands

Command	Effect on Model 2700
REN	Goes into effect when next addressed to listen.
IFC	Goes into talker and listener idle states.
LLO	LOCAL key locked out.
GTL	Cancel remote; restore Model 2700 front panel operation.
	Cancel remote; restore front panel operation for all devices.
DCL	Returns all devices to known conditions.
SDC	Returns Model 2700 to known conditions.
GET	Initiates a trigger.
SPE, SPD	Serial polls the Model 2700.

REN (remote enable)

The remote enable command is sent to the Model 2700 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote mode before you attempt to program it over the bus. Setting REN true does not place the instrument in the remote state. You must address the instrument to listen after setting REN true before it goes into remote.

The Model 2700 must be in remote in order to use the following commands to trigger and acquire readings:

- :INITiate and then :FETCh?
- :READ?
- :MEASure?

IFC (interface clear)

The IFC command is sent by the controller to place the Model 2700 in the local, talker, listener idle states. The unit responds to the IFC command by cancelling front panel TALK or LSTN lights, if the instrument was previously placed in one of these states.

Note that this command does not affect the status of the instrument. Settings, data, and event registers are not changed.

With auto output off enabled (:SOURce1:CLEar:AUTO ON), the output will remain on if operation is terminated before the output has a chance to automatically turn off.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100µs.

LLO (local lockout)

Use the LLO command to prevent local operation of the instrument. After the unit receives LLO, all of its front panel controls except OUTPUT OFF are inoperative. In this state, pressing LOCAL will not restore control to the front panel. The GTL command restores control to the front panel. Cycling power will also cancel local lockout.

GTL (go to local)

Use the GTL command to put a remote-mode instrument into local mode. The GTL command also restores front panel key operation.

DCL (device clear)

Use the DCL command to clear the GPIB interface and return it to a known state. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously.

When the Model 2700 receives a DCL command, it clears the Input Buffer and Output Queue, cancels deferred commands, and clears any command that prevents the processing of any other device command. A DCL does not affect instrument settings and stored data.

SDC (selective device clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL.

GET (group execute trigger)

GET is a GPIB trigger that is used as a trigger event to control operation. The Model 2700 reacts to this trigger if it is the programmed trigger control source. The following command selects the GPIB trigger control source:

```
:TRIGger:SOURce BUS
```

When a GPIB trigger is sent to the Model 2700, operation will continue in the trigger model. See Section 7 for details on triggering.

SPE, SPD (serial polling)

Use the serial polling sequence to obtain the Model 2700 serial poll byte. The serial poll byte contains important information about internal functions. (See "Status structure" in Section 10.) Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the status byte from the Model 2700.

Front panel GPIB operation

This section describes aspects of the front panel that are part of GPIB operation, including messages, status indicators, and the LOCAL key.

Error and status messages

See appendix for a list of error and status messages associated with IEEE-488 programming. The instrument can be programmed to generate an SRQ, and command queries can be performed to check for specific error conditions.

GPIB status indicators

The REM (remote), TALK (talk), LSTN (listen), and SRQ (service request) annunciators show the GPIB bus status. Each of these indicators is described below.

REM

This indicator shows when the instrument is in the remote state. REM does not necessarily indicate the state of the bus REN line, as the instrument must be addressed to listen with REN true before the REM indicator turns on. When the instrument is in remote, all front panel keys, except for the LOCAL key, are locked out. When REM is turned off, the instrument is in the local state, and front panel operation is restored.

NOTE *If LLO is in effect, LOCAL will be locked out. If TRIGger:SOURce is set to manual, the TRIG key will be active in remote.*

TALK

This indicator is on when the instrument is in the talker active state. Place the unit in the talk state by addressing it to talk with the correct MTA (My Talk Address) command. TALK is off when the unit is in the talker idle state. Place the unit in the talker idle state by sending an UNT (Untalk) command, addressing it to listen, or sending the IFC (Interface Clear) command.

LSTN

This indicator is on when the Model 2700 is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. LSTN is off when the unit is in the listener idle state. Place the unit in the listener idle state by sending UNL (Unlisten), addressing it to talk, or sending IFC (Interface Clear) command over the bus.

SRQ

You can program the instrument to generate a service request (SRQ) when one or more errors or conditions occur. When this indicator is on, a service request has been generated. This indicator stays on until the serial poll byte is read or all the conditions that caused SRQ have been cleared. See "Status structure" in Section 15 for more information.

LOCAL key

The LOCAL key cancels the remote state and restores local operation of the instrument.

Pressing the LOCAL key also turns off the REM indicator and returns the display to normal if a user-defined message was displayed.

If the LLO (Local Lockout) command is in effect, the LOCAL key is also inoperative.

For safety reasons, the OUTPUT key will still be active in LLO.

Programming syntax

The information in this section covers syntax for both common commands and SCPI commands. For information not covered here, see the IEEE- 488.2 and SCPI standards. See Sections 11 through 14 for more details on common and SCPI commands.

Command words

Program messages are made up of one or more command words.

Commands and command parameters

Common commands and SCPI commands may or may not use a parameter. The following are some examples:

*SAV <NRf>	Parameter (NRf) required
*RST	No parameter used
:SYSTem:BEEPer <b>	Parameter <b> required
:SYSTem:PRESet	No parameter used

NOTE *At least one space between the command word and the parameter is required.*

Brackets [ ] — Some command words are enclosed in brackets ([ ]). These brackets are used to denote an optional command word that does not need to be included in the program message. For example:

:INITiate[:IMMediate]

These brackets indicate that :IMMediate is implied (optional) and does not have to be used. Thus, the above command can be sent in one of two ways:

:INITiate
or
:INITiate:IMMediate

Notice that the optional command is used without the brackets. When using optional command words in your program, do not include the brackets.

Parameter types — The following are some of the more common parameter types:

<b> Boolean – Used to enable or disable an instrument operation. 0 or OFF disables the operation, and 1 or ON enables the operation. Example:

:SYSTem:LSYNc ON Enable line synchronization

<name> Name parameter – Select a parameter name from a listed group. Example:

<name> = NEVer
= NEXt
= ALWays

:TRACe:FEED:CONTrol NEXt

<NRf> Numeric representation format – This parameter is a number that can be expressed as an integer (e.g., 8), a real number (e.g., 23.6), or an exponent (2.3E6). Example:

:SYSTem:KEY 11 Press EXIT key from over the bus

<n> Numeric value – A numeric value parameter can consist of an NRf number or one of the following name parameters: DEFault, MINimum, MAXimum. When the DEFault parameter is used, the instrument is programmed to the *RST default value. When the MINimum parameter is used, the instrument is programmed to the lowest allowable value. When the MAXimum parameter is used, the instrument is programmed to the largest allowable value. Examples:

:ARM:TIMer 0.1 Sets timer to 100 msec.
:ARM:TIMer DEFault Sets timer to 0.1 sec.
:ARM:TIMer MINimum Sets timer to 1 msec.
:ARM:TIMer MAXimum Sets timer to 99999.99 sec.

<clist> Channel list – Specify one or more channels. Example:

:ROUTe:SCAN (@101:110) Scan list; slot 1, channels 1- 10

<list> List – Specify one or more numbers for a list. Example:

:STATus:QUEue:ENABle (-110:-222) Enable errors -110 through -222

Angle brackets < > Angle brackets (< >) are used to denote a parameter type. Do not include the brackets in the program message. For example:

:RATio <b>

The <b> indicates a Boolean-type parameter is required. Therefore, to enable channel ration, you must send the command with the ON or 1 parameter as follows:

:RATio ON
:RATIO 1

Query commands

This type of command requests (queries) the presently programmed status. It is identified by the question mark (?) at the end of the fundamental form of the command. Most commands have a query form:

:TRIGger:TIMer? Queries the timer interval.

Most commands that require a numeric parameter (<n>) can also use the DEFault, MINimum, and MAXimum parameters for the query form. These query forms are used to determine the *RST default value and the upper and lower limits for the fundamental command. Examples are:

:TRIGger:TIMer? DEFault	Queries the *RST default value.
:TRIGger:TIMer? MINimum	Queries the lowest allowable value.
:TRIGger:TIMer? MAXimum	Queries the largest allowable value.

Case sensitivity

Common commands and SCPI commands are not case sensitive. You can use upper or lower case and any case combination. Examples:

*RST	=	*rst
:DATA?	=	:data?
:SYSTem:PRESet	=	:system:preset

NOTE *Using all upper case will result in slightly faster command response times.*

Long-form and short-form versions

A SCPI command word can be sent in its long-form or short-form version. The command subsystem tables in Section 18 provide the long-form version. However, the short-form version is indicated by upper case characters. Examples:

:SYSTem:PRESet	long-form
:SYST:PRES	short-form
:SYSTem:PRES	long-form and short-form combination

Note that each command word must be in long-form or short-form, and not something in between. For example, :SYSTe:PRESe is illegal and will generate an error. The command will not be executed.

Short-form rules

Use the following rules to determine the short-form version of any SCPI command:

- If the length of the command word is four letters or less, no short form version exists. Example:

  :auto = :auto

These rules apply to command words that exceed four letters:

- If the fourth letter of the command word is a vowel (including "y"), delete it and all the letters after it. Example

  :immediate = :imm

- If the fourth letter of the command word is a consonant, retain it but drop all the letters after it. Example:

  :format = :form

- If the command contains a question mark (?; query) or a non-optional number included in the command word, you must include it in the short-form version. Example:

  :delay? = :del?

- Command words or characters that are enclosed in brackets ([ ]) are optional and need not be included in the program message.

NOTE *For fastest response to commands, always use short forms.*

Program messages

A program message is made up of one or more command words sent by the computer to the instrument. Each common command is a three letter acronym preceded by an asterisk (*). SCPI commands are categorized in the :STATus subsystem and are used to explain how command words are structured to formulate program messages.

```
:STATus                    Path (Root)
  :OPERation                 Path
    :ENABle <NRf>              Command and parameter
  :ENABle?                   Query command
:PRESet                    Command
```

Single command messages

The above command structure has three levels. The first level is made up of the root command (:STATus) and serves as a path. The second level is made up of another path (:OPERation) and a command (:PRESet). The third path is made up of one command for the :OPERation path. The three commands in this structure can be executed by sending three separate program messages as follows:

```
:stat:oper:enab <NRf>
:stat:oper:enab?
:stat:pres
```

In each of the above program messages, the path pointer starts at the root command (:stat) and moves down the command levels until the command is executed.

Multiple command messages

You can send multiple command messages in the same program message as long as they are separated by semicolons (;). The following is an example showing two commands in one program message:

```
:stat:oper; :stat:oper:enab <NRf>
```

When the above is sent, the first command word is recognized as the root command (:stat). When the next colon is detected, the path pointer moves down to the next command level and executes the command. When the path pointer sees the colon after the semicolon (;), it resets back to the root level and starts over.

Commands that are on the same command level can be executed without having to retype the entire command path. Example:

```
:stat:oper:enab <NRf>; enab?
```

After the first command (:enab) is executed, the path pointer is at the third command level in the structure. Since :enab? is also on the third level, it can be typed in without repeating the entire path name. Notice that the leading colon for :enab? is not included in the program message. If a colon were included, the path pointer would reset to the root level and expect a root command. Since :enab? is not a root command, an error would occur.

Command path rules

- Each new program message must begin with the root command, unless it is optional (e.g., [:SENSe]). If the root is optional, simply treat a command word on the next level as the root. For fastest operation, do not send optional data.
- The colon (:) at the beginning of a program message is optional and need not be used. However, eliminating the first colon will result in fastest operation. Example:

  :stat:pres = stat:pres
- When the path pointer detects a colon (:) it moves down to the next command level. An exception is when the path pointer detects a semicolon (;), which is used to separate commands within the program message (see next rule).
- When the path pointer detects a colon (:) that immediately follows a semicolon (;), it resets back to the root level.
- The path pointer can only move down. It cannot be moved up a level. Executing a command at a higher level requires that you start over at the root command.

Using common and SCPI commands in the same message

Both common commands and SCPI commands can be used in the same message as long as they are separated by semicolons (;). A common command can be executed at any command level and will not affect the path pointer. Example:

:stat:oper:enab <NRf>; *ESE <NRf>

Program message terminator (PMT)

Each program message must be terminated with an LF (line feed), EOI (end or identify), or an LF+EOI. The bus will hang if your computer does not provide this termination. The following example shows how a multiple command program message must be terminated:

:outp on <PMT>

Command execution rules

- Commands execute in the order that they are presented in the program message.
- An invalid command generates an error and, of course, is not executed.
- Valid commands that precede an invalid command in a multiple command program message are executed.
- Valid commands that follow an invalid command in a multiple command program message are ignored.

Response messages

A response message is the message sent by the instrument to the computer in response to a query command program message.

Sending a response message

After sending a query command, the response message is placed in the Output Queue. When the Model 2700 is then addressed to talk, the response message is sent from the Output Queue to the computer.

Multiple response messages

If you send more than one query command in the same program message (see "Multiple command messages"), the multiple response messages for all the queries are sent to the computer when the Model 2700 is addressed to talk. The responses are sent in the order the query commands were sent and are separated by semicolons (;). Items within the same query are separated by commas (,). The following example shows the response message for a program message that contains four single item query commands:

0; 1; 1; 0

Response message terminator (RMT)

Each response is terminated with an LF (line feed) and EOI (end or identify). The following example shows how a multiple response message is terminated:

0; 1; 1; 0 <RMT>

Message exchange protocol

Two rules summarize the message exchange protocol:

Rule 1. You must always tell the Model 2700 what to send to the computer.

The following two steps must always be performed to send information from the instrument to the computer:

1. Send the appropriate query command(s) in a program message.
2. Address the Model 2700 to talk.

Rule 2. The complete response message must be received by the computer before another program message can be sent to the Model 2700.

RS-232 interface operation

Sending and receiving data

The RS-232 interface transfers data using 8 data bits, 1 stop bit, and no parity. Make sure the controller you connect to the multimeter also uses these settings.

You can break data transmissions by sending a ^C (decimal 3) or ^X (decimal 18) character string to the instrument. This clears any pending operation and discards any pending output.

Baud rate

The baud rate is the rate at which the Model 2700 multimeter and the programming terminal communicate. Choose one these available rates:

- 19.2k
- 9600
- 4800
- 2400
- 1200
- 600
- 300

The factory selected baud rate is 4800.

When you choose a baud rate, make sure that the programming terminal that you are connecting to the Model 2700 can support the baud rate you selected. Both the multimeter and the other device must be configured for the same baud rate.

Signal handshaking (flow control)

Signal handshaking between the controller and the instrument allows the two devices to communicate to each other regarding being ready or not ready to receive data. The Model 2700 does not support hardware handshaking (flow control).

Software flow control is in the form of X__ON and X__OFF characters and is enabled when XonXoFF is selected from the RS232 FLOW menu. When the input queue of the Model 2700 becomes more than ¾ full, the instrument issues an X_OFF command. The control program should respond to this and stop sending characters until the Model 2700 issues the X_ON, which it will do once its input buffer has dropped below half-full. The Model 2700 recognizes X_ON and X_OFF sent from the controller. An X_OFF will cause the Model 2700 to stop outputting characters until it sees an X_ON. Incoming commands are processed after the <CR> character is received from the controller.

XonXoFF is the FACT and *RST default flow control setting.

If NONE is the selected flow control, then there will be no signal handshaking between the controller and the Model 2700. Data will be lost if transmitted before the receiving device is ready.

Terminator

The Model 2700 can be configured to terminate each program message that it transmits to the controller with any of the following combinations of <CR> and <LF>.

<CR>	Carriage return
<CR+LF>	Carriage return and line feed
<LF>	Line feed
<LF+CR>	Line feed and carriage return

Selecting and configuring RS-232 interface

After selecting (enabling) the RS-232 interface, you will then set the baud rate, flow control and terminator.

1. Press the SHIFT key and then the RS-232 key. The RS 232 ON or RS 232 OFF message will be displayed.
2. If the RS-232 is already ON, press ENTER and proceed to step 3. Otherwise, press the ▶ key to place the cursor on OFF, press the ▲ or ▼ key to display the ON state, and then press ENTER.

NOTE *Enabling (ON) the RS-232 interface disables (OFF) the GPIB. Disabling the RS-232 interface enables the GPIB.*

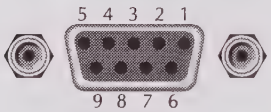
3. To retain the presently displayed BAUD rate, press ENTER and proceed to step 4. Otherwise, press the ▶ key to place the cursor on the baud rate value, use the ▲ or ▼ key to display the desired baud rate, and then press ENTER.
4. To retain the presently displayed FLOW control, press ENTER and proceed to step 5. Otherwise, press the ▶ key to place the cursor on the flow control setting, use the ▲ or ▼ key to display the alternate flow control setting, and then press ENTER.
5. To retain the presently displayed terminator (Tx TERM), press ENTER. Otherwise, press the ▶ key to place the cursor on the terminator setting, use the ▲ or ▼ key to display the desired terminator, and then press ENTER.

RS-232 connections

The RS-232 serial port is connected to the serial port of a computer using a straight-through RS-232 cable terminated with DB-9 connectors. **Do not use a null modem cable.** The serial port uses the transmit (TXD), receive (RXD), and signal ground (GND) lines of the RS-232 standard. Figure 9-4 shows the rear panel connector for the RS-232 interface, and Table 9-2 shows the pinout for the connector.

If your computer uses a DB-25 connector for the RS-232 interface, you will need a cable or adapter with a DB-25 connector on one end and a DB-9 connector on the other, wired straight through (not null modem).

Figure 9-4
RS-232 interface connector



Rear Panel Connector

Table 9-2
RS-232 connector pinout

Pin number	Description
1	No connection
2	TXD, transmit data
3	RXD, receive data
4	No connection
5	GND, signal ground
6	Not used
7	RTS, ready to send
8	CTS, clear to send
9	No connection

NOTE: CTS and RTS are tied together.

Table 9-3 provides pinout identification for the 9-pin (DB-9) or 25-pin (DB-25) serial port connector on the computer (PC).

Table 9-3
PC serial port pinout

Signal	DB-9 pin number	DB-25 pin number
DCD, data carrier detect	1	8
RXD, receive data	2	3
TXD, transmit data	3	2
DTR, data terminal ready	4	20
GND, signal ground	5	7
DSR, data set ready	6	6
RTS, request to send	7	4
CTS, clear to send	8	5
RI, ring indicator	9	22

Error messages

See appendix for RS-232 error messages.

10
Status Structure

- **Overview** — Provides an operational overview of the status structure for the Model 2700.
- **Clearing registers and queues** — Covers the actions that clear (reset) registers and queues.
- **Programming and reading registers** — Explains how to program enable registers and read any register in the status structure.
- **Status byte and service request (SRQ)** — Explains how to program the Status Byte to generate service requests (SRQs). Shows how to use the serial poll sequence to detect SRQs.
- **Status register sets** — Provides bit identification and command information for the four status register sets; Standard Event Status, Operation Event Status, Measurement Event Status, and Questionable Event Status.
- **Queues** — Provides details and command information on the Output Queue and Error Queue.

Overview

The Model 2700 provides a series of status registers and queues allowing the operator to monitor and manipulate the various instrument events. The status structure is shown in Figure 10-1. The heart of the status structure is the Status Byte Register. This register can be read by the user's test program to determine if a service request (SRQ) has occurred, and what event caused it.

Status byte and SRQ

The Status Byte Register receives the summary bits of four status register sets and two queues. The register sets and queues monitor the various instrument events. When an enabled event occurs, it sets a summary bit in the Status Byte Register. When a summary bit of the Status Byte is set and its corresponding enable bit is set (as programmed by the user), the RQS/MSS bit will set to indicate that an SRQ has occurred.

Status register sets

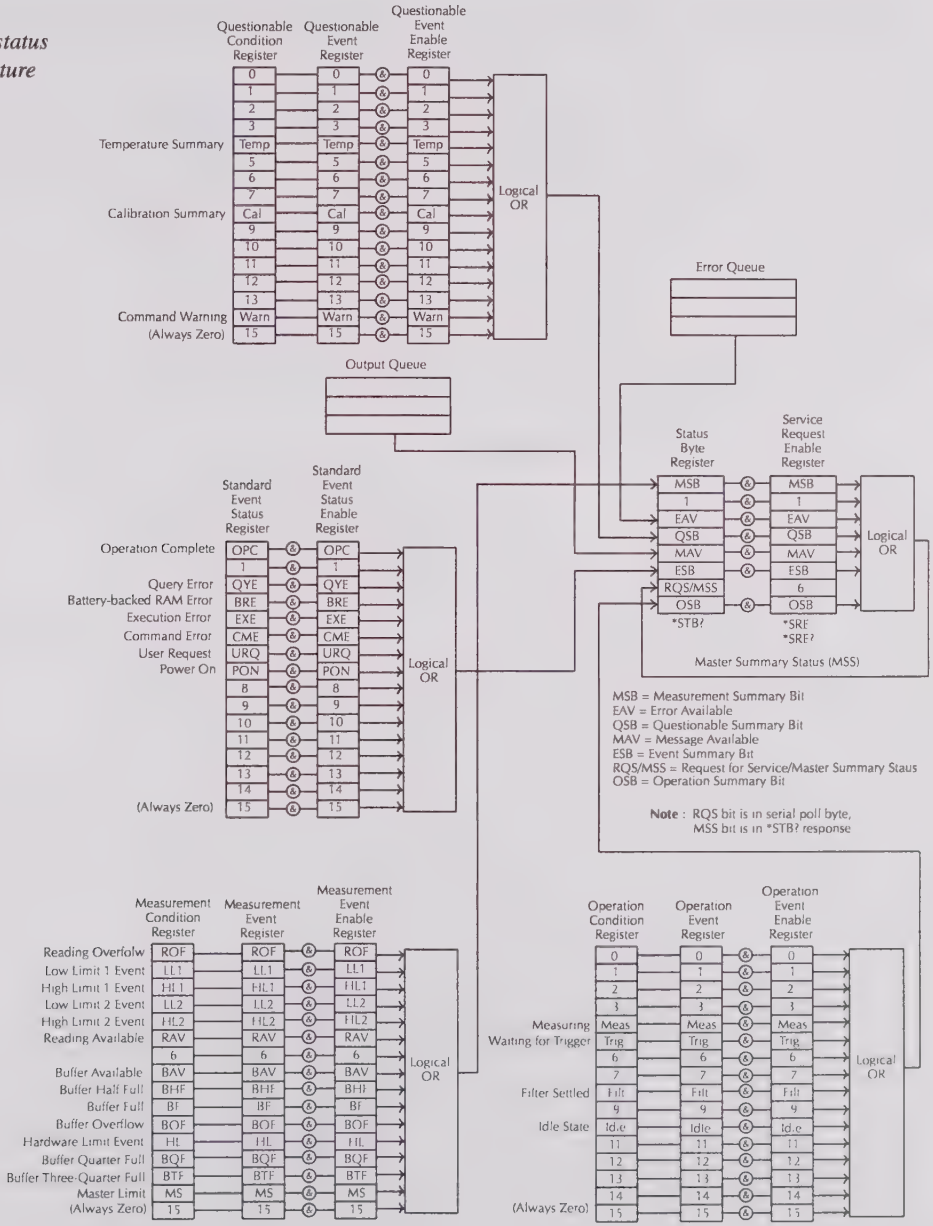
A typical status register set is made up of a condition register, an event register and an event enable register. A condition register is a read-only register that constantly updates to reflect the present operating conditions of the instrument.

When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. When an event register bit is set and its corresponding enable bit is set (as programmed by the user), the output (summary) of the register will set to 1, which in turn sets the summary bit of the Status Byte Register.

Queues

The Model 2700 uses an Output Queue and an Error Queue. The response messages to query commands are placed in the Output Queue. As various programming errors and status messages occur, they are placed in the Error Queue. When a queue contains data, it sets the appropriate summary bit of the Status Byte Register.

Figure 10-1
Model 2700 status register structure



Clearing registers and queues

When the Model 2700 is turned on, the bits of all registers in the status structure are cleared (reset to 0), and the two queues are empty. Commands to reset the event and event enable registers, and the Error Queue are listed in Table 10-1. In addition to these commands, any enable register can be reset by sending the 0 parameter value with the individual command to program the register.

*NOTE SYSTem:PRESet and *RST have no effect on status structure registers and queues.*

Table 10-1
Common and SCPI commands to reset registers and clear queues

Commands	Description	Notes
To Reset Registers:		
*CLS	Reset all bits of the following event registers to 0: Standard Event Register Operation Event Register Measurement Event Register Questionable Event Register	1
:STATus:PRESet	Reset all bits of the following enable registers to 0: Operation Event Enable Register Measurement Event Enable Register Questionable Event Enable Register	1
To Clear Error Queue:		
*CLS	Clear all messages from Error Queue	2
:STATus:QUEue:CLEar	Clear messages from Error Queue	3
:SYSTem:CLEar	Clear messages from Error Queue	3

Notes:
1. The Standard Event Enable Register is not reset by STATus:PRESet or *CLS. Send the 0 parameter value with *ESE to reset all bits of that enable register to 0 (see "Status byte and service request commands").
2. STATus:PRESet has no effect on the Error Queue.
3. Use either of the two clear commands to clear the Error Queue.

Programming and reading registers

Programming enable registers

The only registers that can be programmed by the user are the enable registers. All other registers in the status structure are read-only registers. The following explains how to ascertain the parameter values for the various commands used to program enable registers. The actual commands are covered later in this section (see Table 10-2 and Table 10-5).

A command to program an event enable register is sent with a decimal parameter value that determines the desired state (0 or 1) of each bit in the appropriate register. The bit positions of the register (see Figure 10-2) indicate the binary parameter value. For example, if you wish to set bits B4, B3, and B1, the binary value would be 11010 (where B4=1, B3=1, B1=1, and all other bits are 0).

The binary value is then converted to its decimal equivalent:

Binary 11010 = Decimal 26

Figure 10-2 includes the decimal weight for each register bit. To set bits B4, B3, and B1, the decimal parameter value would be the sum of the decimal weights for those bits (16+8+2 = 26).

Figure 10-2
16-bit status register

A) Bits 0 through 7

Bit Position	B7	B6	B5	B4	B3	B2	B1	B0
Binary Value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal Weights	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)

B) Bits 8 through 15

Bit Position	B15	B14	B13	B12	B11	B10	B9	B8
Binary Value	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal Weights	32768 (2^{15})	16384 (2^{14})	8192 (2^{13})	4096 (2^{12})	2048 (2^{11})	1024 (2^{10})	512 (2^9)	256 (2^8)

Reading registers

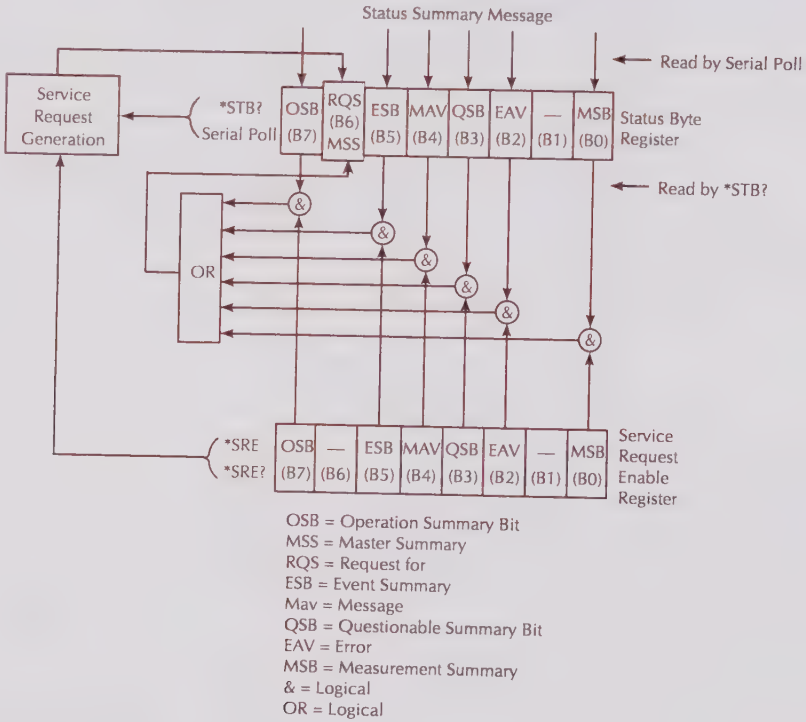
Any register in the status structure can be read by using the appropriate query (?) command. The following explains how to interpret the returned value (response message). The actual query commands are covered later in this section (see Table 10-2 through Table 10-5).

The response message for a register query will be a decimal value. This decimal value will have to be converted to its binary equivalent. For example, decimal 19 in binary is 10011. This binary value indicates that bits B0, B1 and B4 are set (1).

Status byte and service request (SRQ)

Service request is controlled by two 8-bit registers; the Status Byte Register and the Service Request Enable Register. Figure 10-3 shows the structure of these registers.

Figure 10-3
Status byte and service request (SRQ)



Status byte register

The summary messages from the status registers and queues are used to set or clear the appropriate bits (B0, B2, B3, B4, B5, and B7) of the Status Byte Register. These summary bits do not latch, and their states (0 or 1) are solely dependent on the summary messages (0 or 1). For example, if the Standard Event Register is read, its register will clear. As a result, its summary message will reset to 0, which in turn will reset the ESB bit in the Status Byte Register.

The bits of the Status Byte Register are described as follows:

- **Bit B0, Measurement Summary Bit (MSB)** — Set summary bit indicates that an enabled measurement event has occurred.
- **Bit B1** — Not used.
- **Bit B2, Error Available (EAV)** — Set summary bit indicates that an error or status message is present in the Error Queue.
- **Bit B3, Questionable Summary Bit (QSB)** — Set summary bit indicates that an enabled questionable event has occurred.
- **Bit B4, Message Available (MAV)** — Set summary bit indicates that a response message is present in the Output Queue.
- **Bit B5, Event Summary Bit (ESB)** — Set summary bit indicates that an enabled standard event has occurred.
- **Bit B6, Request Service (RQS)/Master Summary Status (MSS)** — Set bit indicates that an enabled summary bit of the Status Byte Register is set.
- **Bit B7, Operation Summary (OSB)** — Set summary bit indicates that an enabled operation event has occurred.

Depending on how it is used, Bit B6 of the Status Byte Register is either the Request for Service (RQS) bit or the Master Summary Status (MSS) bit:

- When using the serial poll sequence of the Model 2700 to obtain the status byte (a.k.a. serial poll byte), B6 is the RQS bit. See "Serial polling and SRQ" for details on using the serial poll sequence.
- When using the *STB? command (see Table 10-2) to read the status byte, B6 is the MSS bit.

Service request enable register

The generation of a service request is controlled by the Service Request Enable Register. This register is programmed by you and is used to enable or disable the setting of bit B6 (RQS/MSS) by the Status Summary Message bits (B0, B2, B3, B4, B5, and B7) of the Status Byte Register. As shown in Figure 10-3, the summary bits are logically ANDed (&) with the corresponding enable bits of the Service Request Enable Register. When a set (1) summary bit is ANDed with an enabled (1) bit of the enable register, the logic "1" output is applied to the input of the OR gate and, therefore, sets the MSS/RQS bit in the Status Byte Register.

The individual bits of the Service Request Enable Register can be set or cleared by using the *SRE common command. To read the Service Request Enable Register, use the *SRE? query command. The Service Request Enable Register clears when power is cycled or a parameter value of 0 is sent with the *SRE command (*SRE 0). The commands to program and read the SRQ Enable Register are listed in Table 10-2.

Serial polling and SRQ

Any enabled event summary bit that goes from 0 to 1 will set bit B6 and generate an SRQ (service request). In your test program, you can periodically read the Status Byte to check if an SRQ has occurred and what caused it. If an SRQ occurs, the program can, for example, branch to an appropriate subroutine that will service the request.

Typically, SRQs are managed by the serial poll sequence of the Model 2700. If an SRQ does not occur, bit B6 (RQS) of the Status Byte Register will remain cleared, and the program will simply proceed normally after the serial poll is performed. If an SRQ does occur, bit B6 of the Status Byte Register will set, and the program can branch to a service subroutine when the SRQ is detected by the serial poll.

The serial poll automatically resets RQS of the Status Byte Register. This allows subsequent serial polls to monitor bit B6 for an SRQ occurrence generated by other event types. After a serial poll, the same event can cause another SRQ, even if the event register that caused the first SRQ has not been cleared.

The serial poll does not clear MSS. The MSS bit stays set until all Status Byte summary bits are reset.

SPE, SPD (serial polling)

The SPE, SPD General Bus Command sequence is used to serial poll the Model 2700. Serial polling obtains the serial poll byte (status byte). Typically, serial polling is used by the controller to determine which of several instruments has requested service with the SRQ line.

Status byte and service request commands

The commands to program and read the Status Byte Register and Service Request Enable Register are listed in Table 10-2. For details on programming and reading registers, see "Programming enable registers" and "Reading registers."

NOTE *To reset the bits of the Service Request Enable Register to 0, use 0 as the parameter value for the *SRE command (*SRE 0).*

Table 10-2
Status byte and service request enable register commands

Command	Description
*STB?	Read Status Byte Register.
*SRE <NRf>	Program the Service Request Enable Register (0 to 255).
*SRE?	Read the Service Request Enable Register.

Note: *CLS and STATus:PRESet have no effect on the Service Request Enable Register.

Programming example — set MSS (B6) when error occurs

The second command in the following sequence enables EAV (error available). When an invalid command is sent (line 3), bits B2 (EAV) and B6 (MSS) of the Status Byte Register set to 1. The last command reads the Status Byte Register. Keep in mind that you have to address the Model 2700 to talk after sending a query command. To determine the exact nature of the error, you will have to read the Error Queue (see "Queues").

```
*CLS                                    ' Clear Error Queue
*SRE 4                                  ' Enable EAV.
*XYZ                                    ' Generate error.
*STB?                                   ' Read Status Byte Register.
```

Serial poll programming example

QuickBASIC 4.5 programming

SRQ on buffer ¼ full, ½ full, ¾ full, and full

The following program will store 2000 readings in the buffer. When the buffer becomes ¼ full, an SRQ will occur and a message will be displayed on the computer to indicate that event. An SRQ and message will also occur for the buffer ½ full, ¾ full, and full events.

NOTE *This example is written specifically for the KPCI-488.2 GPIB card and QuickBasic/ VisualBasic with the appropriate IEEE libraries. Other types of cards and/or languages may have different function calls that are equivalent to the initialize(), transmit(), send(), srq, and spoll() calls used below.*

```
' $INCLUDE: 'ieeeqb.bi'

CLS                                                    ' Clear PC output screen
CONST addr = 16                                        ' Set instrument address.

'
' Init GPIB.
'
CALL initialize(21, 0)
CALL transmit("unt unl listen " + STR$(addr) + " sdc unl", status%)' Send Device Clear.

CALL send(addr, "*rst", status%)                       ' Restore *rst defaults.
CALL send(addr, "trac:cle", status%)                   ' Clear buffer.
CALL send(addr, "trig:coun inf", status%)              ' Infinite trigger count.
CALL send(addr, "trac:poin 2000", status%)             ' Set buffer size to 2000.
CALL send(addr, "trac:feed:cont next", status%)        ' Enable buffer.
CALL send(addr, "stat:pres", status%)                  ' Reset measure enable bits.
CALL send(addr, "*cls", status%)                       ' Clear all event registers.
CALL send(addr, "stat:meas:enab 13056", status%)       ' Enable ¼, ½, ¾, and full buffer bits.
CALL send(addr, "*ese 0", status%)                     ' Disable standard events.
CALL send(addr, "*sre 1", status%)                     ' Enable measurement events.
CALL send(addr, "init", status%)                       ' Start measure/store process.

N = 0                                                  ' Initialize quarter buffer counter.
```

```
WaitSRQ:
            WHILE srq = 0: WEND                    ' Wait for GPIB SRQ line to go true.
            CALL spoll(addr, poll%, status%)       ' Clear rqs/mss bit in status byte register.
            CALL send(addr, "*cls", status%)       ' Clear all event registers .
            N = N + 1                              ' Increment quarter buffer counter.
            IF N = 1 THEN GOTO QtrFull             ' Branch when buffer ¼ full.
            IF N = 2 THEN GOTO HalfFull            ' Branch when buffer ½ full.
            IF N = 3 THEN GOTO ThreeQtrFull        ' Branch when buffer ¾ full.
            PRINT "BUFFER FULL"                    ' Display buffer full message.
END

QtrFull: PRINT "Buffer ¼ Full"                     ' Display ¼ full message.
GOTO WaitSRQ                                       ' Return to WaitSRQ.

HalfFull: PRINT "Buffer ½ Full"                    ' Display ½ full message.
GOTO WaitSRQ                                       ' Return to WaitSRQ.

ThreeQtrFull: PRINT "Buffer ¾ Full"                ' Display ¾ full message.
GOTO WaitSRQ                                       ' Return to WaitSRQ.
```

Status register sets

As shown in Figure 10-1, there are four status register sets in the status structure of the Model 2700; Standard Event Status, Operation Event Status, Measurement Event Status, and Questionable Event Status.

Register bit descriptions

Standard Event Register

The used bits of the Standard Event Register (shown in Figure 10-4) are described as follows:

- **Bit B0, Operation Complete (OPC)** — Set bit indicates that all pending selected device operations are completed and the Model 2700 is ready to accept new commands. This bit only sets in response to the *OPC? query command. See Section 11 for details on *OPC and *OPC?.
- **Bit B1** — Not used.
- **Bit B2, Query Error (QYE)** — Set bit indicates that you attempted to read data from an empty Output Queue.
- **Bit B3, Battery-backed RAM Error (BRE)** — Set bit indicates that the scan cannot be resumed (error +517) or there was a loss of data (error +516).
- **Bit B4, Execution Error (EXE)** — Set bit indicates that the Model 2700 detected an error while trying to execute a command.

- **Bit B5, Command Error (CME)** — Set bit indicates that a command error has occurred.

  Command errors include:

  - IEEE-488.2 syntax error — Model 2700 received a message that does not follow the defined syntax of the IEEE-488.2 standard.
  - Semantic error — Model 2700 received a command that was misspelled or received an optional IEEE-488.2 command that is not implemented.
  - The instrument received a Group Execute Trigger (GET) inside a program message.
- **Bit B6, User Request (URQ)** — Set bit indicates that the LOCAL key on the Model 2700 front panel was pressed.
- **Bit B7, Power On (PON)** — Set bit indicates that the Model 2700 has been turned off and turned back on since the last time this register has been read.

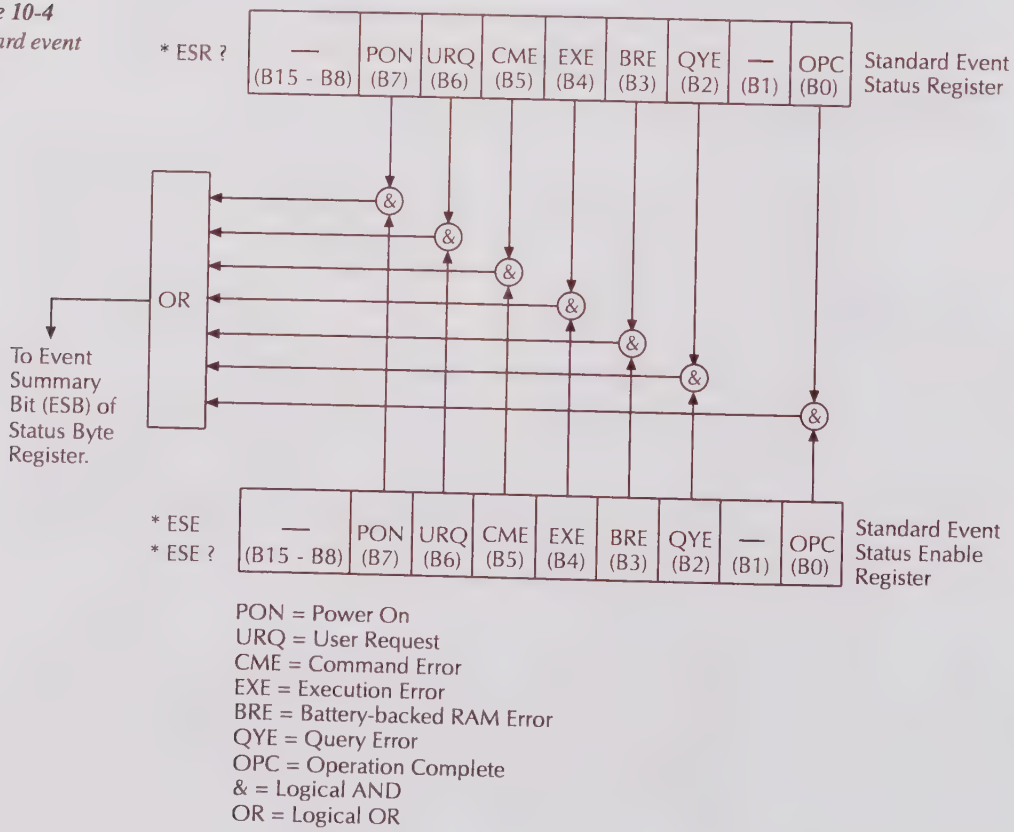


Figure 10-4
Standard event status

Operation event register

The bits of the Operation Event Register (shown in Figure 10-5) are described as follows:

- **Bits B0 through B3** — Not used.
- **Bit B4, Measuring (Meas)** — Set bit indicates that the instrument is performing a measurement.
- **Bit B5, Waiting for Trigger (Trig)** — Set bit indicates that the Model 2700 is in the trigger layer waiting for a trigger event to occur.
- **Bits B6 and B7** — Not used.
- **Bits B8, Filter Settled (Filt)** — Set bit indicates that the filter has settled or the filter is disabled.
- **Bit B9** — Not used.
- **Bit B10, Idle State (Idle)** — Set bit indicates the Model 2700 is in the idle state.
- **Bits B11 through B15** — Not used.

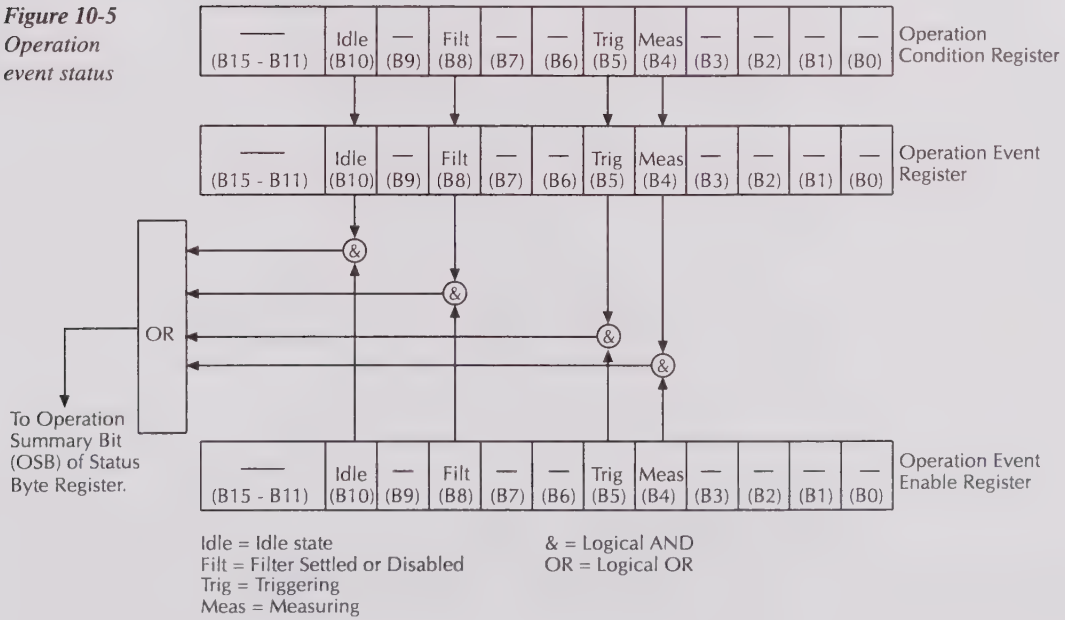


Figure 10-5 Operation event status

Measurement event register

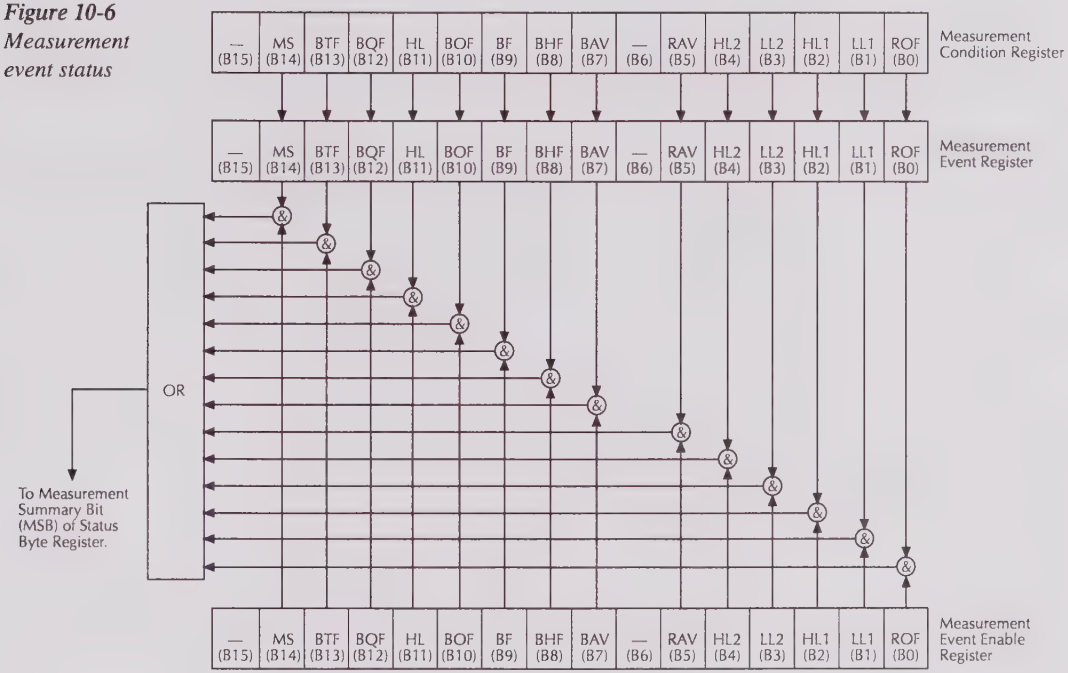
The used bits of the Measurement Event Register (shown in Figure 10-6) are described as follows:

- **Bit B0, Reading Overflow (ROF)** — Set bit indicates that the reading exceeds the measurement range of the instrument.
- **Bit B1, Low Limit 1 Event (LL1)** — Set bit indicates that a reading has reached or exceeded Low Limit 1.
- **Bit B2, High Limit 1 Event (HL1)** — Set bit indicates that a reading has reached or exceeded High Limit 1.
- **Bit B3, Low Limit 2 Event (LL2)** — Set bit indicates that a reading has reached or exceeded Low Limit 2.
- **Bit B4, High Limit 2 Fail (HL2)** — Set bit indicates that a reading has reached or exceeded High Limit 2.
- **Bit B5, Reading Available (RAV)** — Set bit indicates that a reading was taken and processed.
- **Bit B6** — Not used.
- **Bit B7, Buffer Available (BAV)** — Set bit indicates that there are at least two readings in the buffer.
- **Bit B8, Buffer Half Full (BHF)** — Set bit indicates that the trace buffer is half full.
- **Bit B9, Buffer Full (BF)** — Set bit indicates that the trace buffer is full.
- **Bit B10, Buffer Overflow (BOF)** — Set bit indicates that the filled buffer has wrapped and written over previously stored readings.
- **Bit B11, Hardware Limit Event (HL)** — Set bit indicates that a reading has exceeded the hardware limit.
- **Bit B12, Buffer Quarter Full (BQF)** — Set bit indicates that the trace buffer is one-quarter full.

NOTE *Bits B12 (¼ full) and B13 (¾ full) are not intended to be used with buffer sizes smaller than four readings.*

- **Bit B13, Buffer Three-Quarter Full (BTF)** — Set bit indicates that the trace buffer is three-quarters full.
- **Bit B14, Master Limit (ML)** — Set bit indicates that one or more of the other limits have been reached or exceeded.
- **Bit B15** — Not used.

Figure 10-6
Measurement event status


— (B15) MS (B14) BTF (B13) BQF (B12) HL (B11) BOF (B10) BF (B9) BHF (B8) BAV (B7) — (B6) RAV (B5) HL2 (B4) LL2 (B3) HL1 (B2) LL1 (B1) ROF (B0)
Measurement Condition Register
Measurement Event Register
OR
To Measurement Summary Bit (MSB) of Status Byte Register.
Measurement Event Enable Register

MS = Master Limit
BTF = Buffer Three-quarter Full
BQF = Buffer Quarter Full
HL = Hardware Limit Event
BOF = Buffer Overflow
BF = Buffer Full
BHF = Buffer Half Full

BAV = Buffer Available
RAV = Reading Available
HL2 = High Limit 2 Event
LL2 = Low Limt 2 Event
HL1 = High Limit 1 Event
LL1 = Low Limit 1 Event
ROF = Reading Overflow

& = Logical AND
OR = Logical OR

Questionable event register

The used bits of the Questionable Event Register (shown in Figure 10-7) are described as follows:

- **Bits B0 through B3** — Not used.
- **Bit B4, Temperature Summary (Temp)** — Set bit indicates that an invalid reference junction measurement has occurred for thermocouple temperature measurements.
- **Bits B5, B6 and B7** — Not used.
- **Bit B8, Calibration Summary (Cal)** — Set bit indicates that an invalid calibration constant was detected during the power-up sequence. The instrument will instead use a default calibration constant. This error will clear after successful calibration of the instrument.
- **Bits B9 through B13** — Not used.
- **Bit B14, Command Warning (Warn)** — Set bit indicates that a Signal Oriented Measurement Command parameter has been ignored.

NOTE *Whenever a questionable event occurs, the ERR annunciator will turn on. The annunciator will turn off when the questionable event clears.*

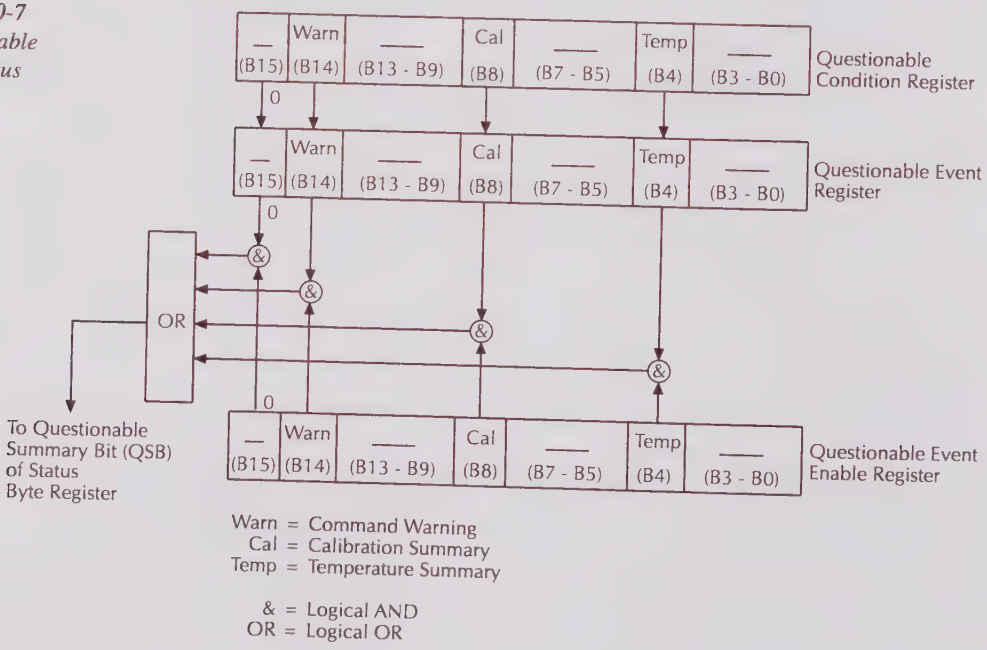


Figure 10-7 Questionable event status

Condition registers

As Figure 10-1 shows, each status register set (except the Standard Event Register set) has a condition register. A condition register is a real-time, read-only register that constantly updates to reflect the present operating conditions of the instrument. For example, while the Model 2700 is in the idle state, bit B10 (Idle) of the Operation Condition Register will be set. When the instrument is taken out of idle, bit B10 clears.

The commands to read the condition registers are listed in Table 10-3. For details on reading registers, see "Reading registers."

Table 10-3
Condition register commands

Command	Description
:STATus:OPERation:CONDition?	Read Operation Condition Register.
:STATus:MEASurement:CONDition?	Read Measurement Condition Register.
:STATus:QUEStionable:CONDition?	Read Questionable Condition Register.

Event registers

As Figure 10-1 shows, each status register set has an event register. When an event occurs, the appropriate event register bit sets to 1. The bit remains latched to 1 until the register is reset. Reading an event register clears the bits of that register. *CLS resets all four event registers.

The commands to read the event registers are listed in Table 10-4. For details on reading registers, see "Reading registers."

Table 10-4
Event register commands

Command	Description
*ESR?	Read Standard Event Status Register.
:STATus:OPERation:[:EVENt]?	Read Operation Event Register.
:STATus:MEASurement:[:EVENt]?	Read Measurement Event Register.
:STATus:QUEStionable:[:EVENt]?	Read Questionable Event Register.

Note: Power-up and *CLS resets all bits of all event registers to 0. STATus:PRESet has no effect.

Event enable registers

As Figure 10-1 shows, each status register set has an enable register. Each event register bit is logically ANDed (&) to a corresponding enable bit of an enable register. Therefore, when an event bit is set and the corresponding enable bit is set (as programmed by the user), the output (summary) of the register will set to 1, which in turn sets the summary bit of the Status Byte Register.

The commands to program and read the event enable registers are listed in Table 10-5. For details on programming and reading registers, see "Programming enable registers" and "Reading registers."

NOTE *The bits of any enable register can be reset to 0 by sending the 0 parameter value with the appropriate enable command (i.e. STATus:OPERation:ENABle 0).*

Table 10-5
Event enable registers commands

Command	Description
*ESE <NRf>	Program Standard Event Enable Register (0 to 255).
*ESE?	Read Standard Event Enable Register.
STATus:OPERation:ENABle <NRF>	Program Operation Event Enable Register (0 to 65535).
STATus:OPERation:ENABle?	Read enable register.
STATus:MEASurement:ENABle <NRf>	Program Measurement Event Enable Register (0 to 65535).
STATus:MEASurement:ENABle?	Read enable register.
STATus:QUEStionable:ENABle <NRf>	Program Questionable Event Enable Register (0 to 65535).
STATus:QUEStionable:ENABle?	Read enable register.

Note: Power-up and STATus:PRESet resets all bits of all enable registers to 0. *CLS has no effect.

Programming example — program and read register set

The following command sequence programs and reads the measurement register set. Keep in mind that the Model 2700 has to be addressed to talk after a query command.

```
STAT:MEAS:ENAB 512          ' Enable BFL (buffer full).
STAT:MEAS:COND?             ' Read Measurement Condition Register.
STAT:MEAS?                  ' Read Measurement Event Register.
```

Queues

The Model 2700 uses two queues, which are first-in, first-out (FIFO) registers:

- Output Queue — Used to hold reading and response messages.
- Error Queue — Used to hold error and status messages.

The Model 2700 status model (Figure 10-1) shows how the two queues are structured with the other registers.

Output queue

The output queue holds data that pertains to the normal operation of the instrument. For example, when a query command is sent, the response message is placed in the Output Queue.

When data is placed in the Output Queue, the Message Available (MAV) bit in the Status Byte Register sets. A data message is cleared from the Output Queue when it is read. The Output Queue is considered cleared when it is empty. An empty Output Queue clears the MAV bit in the Status Byte Register.

A message is read from the Output Queue by addressing the Model 2700 to talk after the appropriate query is sent.

Error queue

The Error Queue holds error and status messages. When an error or status event occurs, a message that defines the error/status is placed in the Error Queue.

When a message is placed in the Error Queue, the Error Available (EAV) bit in the Status Byte Register is set. An error/status message is cleared from the Error Queue when it is read. The Error Queue is considered cleared when it is empty. An empty Error Queue clears the EAV bit in the Status Byte Register.

The Error Queue holds up to 10 error/status messages. The commands to read the Error Queue are listed in Table 10-6. When you read a message in the Error Queue, the "oldest" message is read and then removed from the queue. If the queue becomes full, the message "350, 'Queue Overflow'" will occupy the last memory location. On power-up, the Error Queue is empty. When empty, the message "0, No Error" is placed in the queue.

Messages in the Error Queue are preceded by a code number. Negative (-) numbers are used for SCPI-defined messages, and positive (+) numbers are used for Keithley-defined messages. The messages are listed in the appendices at the end of this manual.

On power-up, all error messages are enabled and will go into the Error Queue as they occur. Status messages are not enabled and will not go into the queue. As listed in Table 10-6, there are commands to enable and/or disable messages. For these commands, the <list> parameter is used to specify which messages to enable or disable. The messages are specified by their codes. The following examples show various forms for using the <list> parameter.

<list> = (-110)	Single message
= (-110:-222)	Range of messages (-110 through -222)
= (-110:-222, -220)	Range entry and single entry (separated by a comma)

When you enable messages, messages not specified in the list are disabled. When you disable messages, each listed message is removed from the enabled list.

NOTE *To prevent all messages from entering the Error Queue, send the enable command along with the null list parameter as follows:*

STATus:QUEue:ENABle ().

Table 10-6
Error queue commands

Command	Description	Notes
STATus:QUEue:[:NEXT]?	Read and clear oldest error/status (code and message).	1
STATus:QUEue:ENABle <list>	Specify error and status messages for Error Queue.	2
STATus:QUEue:ENABle?	Read the enabled messages.	
STATus:QUEue:DISable <list>	Specify messages not to be placed in queue.	2
STATus:QUEue:DISable?	Read the disabled messages.	
STATus:QUEue:CLEar	Clear messages from Error Queue.	
SYSTem:ERRor?	Read Error Queue.	1
SYSTem:CLEar	Clear messages from Error Queue.	

Notes:
1. Power-up and *CLS empties the Error Queue. STATus:PRESet has no effect.
2. Power-up enables error messages and disables status messages. *CLS and STATus:PRESet have no effect.

Programming example — read error queue

The following command reads the error queue:

```
STAT:QUE?
```

11
Common Commands

Common commands (summarized in Table 11-1) are device commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard.

Table 11-1
IEEE-488.2 common commands and queries

Mnemonic	Name	Description	Ref
*CLS	Clear status	Clears all event registers and error queue.	Sec 10
*ESE <NRf>	Event enable command	Program the standard event enable register.	Sec 10
*ESE?	Event enable query	Read the standard event enable register.	Sec 10
*ESR?	Event status register query	Read the standard event enable register and clear it.	Sec 10
*IDN?	Identification query	Returns the manufacturer, model number, serial number, and firmware revision levels of the unit.	A
*OPC	Operation complete command	Set the operation complete bit in the standard event register after all pending commands have been executed.	B
*OPC?	Operation complete query	Places an ASCII "1" into the output queue when all pending selected device operations have been completed.	B
*OPT?	Option query	Returns the model numbers of the switching modules installed in the Model 2700. Returns "NONE" if slot is empty.	C
*RCL <NRf>	Recall command	Returns Model 2700 to the user-saved setup.	D
*RST	Reset command	Returns Model 2700 to the *RST default conditions.	E
*SAV <NRf>	Save command	Saves the present setup as the user-saved setup.	D
*SRE <NRf>	Service request enable command	Programs the service request enable register.	Sec 10
*SRE?	Service request enable query	Reads the service request enable register.	Sec 10
*STB?	Status byte query	Reads the status byte register.	Sec 10
*TRG	Trigger command	Sends a bus trigger to Model 2700.	F
*TST?	Self-test query	Performs a checksum test on ROM and returns the result.	G
*WAI	Wait-to-continue command	Wait until all previous commands are executed.	H

M *IDN? — identification query

Reads identification code

The identification code includes the manufacturer, model number, serial number, and firmware revision levels and is sent in the following format:

KEITHLEY INSTRUMENTS INC., Model 2700, xxxxxxx, yyyyy/zzz

Where: xxxxxxx is the serial number.
yyyyy/zzzzz is the firmware revision levels of the digital board ROM and display board ROM.

N *OPC — operation complete

Sets OPC bit

*OPC? — operation complete query

Places a "1" in output queue

When *OPC is sent, the OPC bit in the standard event register will set after all pending command operations are complete. When *OPC? is sent, an ASCII "1" is placed in the output queue after all pending command operations are complete.

Typically, either one of these commands is sent after the INITiate command. The INITiate command is used to take the instrument out of idle in order to perform measurements. While operating within the trigger model layers, all sent commands (except DCL, SDC, IFC, SYSTem:PRESet, *RST, *TRG, GET and ABORt) will not execute.

After all programmed operations are completed, the instrument returns to the idle state at which time all pending commands (including *OPC and/or *OPC?) are executed. After the last pending command is executed, the OPC bit and/or an ASCII "1" is placed in the output queue.

Programming example — The following command sequence will perform 10 measurements. After the measurements are completed (in approximately 10 seconds), an ASCII "1" will be placed in the output queue.

```
*RST                          ' Return 2700 to RST defaults (idle).
TRIG:DEL 1                    ' Set trigger delay for 1 second.
TRIG:COUN 10                  ' Program for 10 measurements and stop.
INIT                          ' Start measurements.
*OPC?                         ' Send *OPC?.
```

O *OPT? — option query

Query installed switching modules

Use this query command to determine which switching modules are installed in the Model 2700. For example, if a Model 7703 is installed in slot 1, and slot 2 is empty, the response message will look like this:

7703, NONE

Note that the model number of an "installed" pseudocard is returned in the same manner. See Section 1 for details on pseudocards.

P *SAV <NRf> — save
*RCL <NRf> — recall

Save present setup in memory
Return to setup stored in memory

Parameters
0 = Memory location 0
1 = Memory location 1
2 = Memory location 2
3 = Memory location 3

Use the *SAV command to save the present instrument setup configuration in memory for later recall. Any control affected by *RST can be saved by the *SAV command. The *RCL command is used to restore the instrument to the saved setup configuration. Three setup configurations can be saved and recalled.

Model 2700 ships from the factory with SYSTem:PRESet defaults loaded into the available setup memory. If a recall error occurs, the setup memory defaults to the SYSTem:PRESet values.

Programming example:

```
*SAV 2              ' Save present setup in memory location 2.
*RST                ' Return 2700 to RST defaults.
*RCL 2              ' Return (recall) 2700 to setup stored in memo location 2.
```

Q *RST — reset

Return Model 2700 to RST defaults

When the *RST command is sent, Model 2700 performs the following operations:

1. Returns Model 2700 to the RST default conditions (see "Default" column of SCPI tables).
2. Cancels all pending commands.
3. Cancels response to any previously received *OPC and *OPC? commands.

R *TRG — trigger

Send bus trigger to Model 2700

Use the *TRG command to issue a GPIB trigger to Model 2700. It has the same effect as a group execute trigger (GET).

Use the *TRG command as an event to control operation. Model 2700 reacts to this trigger if BUS is the programmed arm control source. The control source is programmed from the TRIGger subsystem.

NOTE *Details on triggering are provided in Section 7.*

Programming example — The following command sequence configures Model 2700 to be controlled by bus triggers. The last line, which sends a bus trigger, triggers one measurement. Each subsequent bus trigger will also trigger a single measurement.

```
*RST                                    ' Restore RST defaults.
TRIG:SOUR BUS                           ' Select BUS control source.
TRIG:COUN INF                           ' Set trigger layer count to infinity.
INIT                                    ' Take 2700 out of idle.
*TRG                                    ' Trigger one measurement.
```

S *TST? — self-test query

Run self test and read result

Use this query command to perform a checksum test on ROM. The command places the coded result (0 or 1) in the output queue. When Model 2700 is addressed to talk, the coded result is sent from the output queue to the computer.

A returned value of zero (0) indicates that the test passed, and a value of one (1) indicates that the test failed.

T *WAI — wait-to-continue

Wait until previous commands are completed

Effectively, the *WAI command is a No-Op (no operation) for Model 2700 and thus, does not need to be used.

Two types of device commands exist:

- Sequential commands — A command whose operations are allowed to finish before the next command is executed.
- Overlapped commands — A command that allows the execution of subsequent commands while device operations of the overlapped command are still in progress.

The *WAI command is used to suspend the execution of subsequent commands until the device operations of all previous overlapped commands are finished. The *WAI command is not needed for sequential commands.

12
SCPI Signal Oriented Measurement Commands

The signal oriented measurement commands are used to acquire readings. You can use these high level instructions to control the measurement process. These commands are summarized in Table 12-1.

Table 12-1
Signal oriented measurement command summary

Command	Description
CONFigure:<function> [<, rang>] [<, dig>]	Places the Model 2700 in a "one-shot" measurement mode for the specified function.
:FETCh?	Requests the latest reading.
:READ?	Performs an :ABORt, :INITiate, and a :FETCh?.
MEASure[:<function>]?	Performs an :ABORt, :CONFigure:<function>, and a :READ?.

:CONFigure:<function> [<, rang>] [<, dig>]

Parameters

<function> =	VOLTage[:DC]	DC voltage
	VOLTage:AC	AC voltage
	CURRent:DC	DC current
	CURRent:AC	AC current
	RESistance	2-wire resistance
	FRESistance	4-wire resistance
	TEMPerature	Temperature
	FREQuency	Frequency
	PERiod	Period
	CONTinuity	Continuity test

<, rang> = Valid range parameter for the specified function. For example, for DCV, range parameter value 10 selects the 10V range.

<. dig> = Valid digits parameter to set display resolution. For example, the parameter value 3.5 sets display resolution to 3½ digits.

Query :CONFigure? Query the selected function.

Description

This command configures the instrument for subsequent measurements on the specified function. Range and digits can also be set for the specified function.

This command places the instrument in a "one-shot" measurement mode. You can then use the :READ? command to trigger a measurement and acquire a reading (see :READ?).

When this command is sent, the Model 2700 will be configured as follows:

- The function specified by this command is selected. If specified, range and/or digits are also set.

- All controls related to the selected function are defaulted to the *RST values.
- Continuous initiation is disabled (:INITiate:CONTinuous OFF).
- The control source of the Trigger Model is set to Immediate.
- The count values of the Trigger Model are set to one.
- The delay of the Trigger Model is set to zero.
- The Model 2700 is placed in the idle state.
- All math calculations are disabled.
- Buffer operation is disabled. A storage operation presently in process will be aborted.
- Autozero is set to the *RST default value.
- All operations associated with stepping or scanning are disabled.

This command is automatically asserted when the :MEASure? command is sent.

Programming example — The following command selects DCV function, 10V range, 3½ digit resolution, and performs the CONFigure operations:

```
CONF:VOLT 10, 3.5
```

:FETCh?

Description This command requests the latest post-processed reading. After sending this command and addressing the Model 2700 to talk, the reading is sent to the computer. This command does not affect the instrument setup.

This command does not trigger a measurement. The command simply requests the last available reading.

NOTE *FETCh? can repeatedly return the same reading. Until there is a new reading, this command continues to return the old reading.*

This command is automatically asserted when the :READ? or :MEASure? command is sent.

:READ?

Description This command is typically used with the instrument in the "one-shot" measurement mode to trigger and acquire a specified number of readings. The :SAMPle:COUNt command is used to specify the number of readings (see Trigger Subsystem). Note that the readings are stored in the buffer.

When this command is sent, the following commands execute in the order they are presented:

:ABORt
:INITiate
:FETCh?

When :ABORt is executed, the instrument goes into the idle state if continuous initiation is disabled. If continuous initiation is enabled, the operation re-starts at the beginning of the Trigger Model.

If the instrument is in the idle state, :INITiate takes the instrument out of the idle state. If continuous initiation is enabled, (:INITiate:CONTinuous ON), then the :INITiate command generates error -213 (init ignored).

NOTE *If continuous initiation is enabled, the READ? command will generate error -213 (init ignored). It can be disabled by sending INITiate:CONTinuous OFF. The *RST command can also be used to disable continuous initiation. It also places the Model 2700 in the "one-shot" measurement mode:*

```
*RST        ' Disable continuous initiation and place 2700 in "one-shot" mode.
:READ?      ' Trigger and return one reading.
```

NOTES *You cannot use the :READ? command if sample count >1 (see Trigger Subsystem) and there are readings stored in the buffer (error -225, out of memory). Either set sample count to one or clear the buffer.*

*The buffer of the Model 2700 is nonvolatile. Therefore, readings stored in the buffer are not lost when the instrument is turned off, or when *RST or :SYSTem:PRESet is sent. When writing test programs that perform multi-sample measurements (:SAMPle:COUNTt >1), you may want to add the :TRACe:CLEar command at the beginning to clear the buffer. However, be careful not to inadvertently clear stored readings that are needed.*

:MEASure:<function>?

Parameters

<function> =	VOLTage[:DC]	DC voltage
	VOLTage:AC	AC voltage
	CURRent:DC	DC current
	CURRent:AC	AC current
	RESistance	2-wire resistance
	FRESistance	4-wire resistance
	TEMPerature	Temperature
	FREQuency	Frequency
	PERiod	Period
	CONTinuity	Continuity test

Description

This command combines all of the other signal oriented measurement commands to perform a "one-shot" measurement and acquire the reading. When this command is sent, the following commands execute in the order that they are presented:

:ABORt
:CONFigure:<function>
:READ?

When :ABORt is executed, the instrument goes into the idle state if continuous initiation is disabled. If continuous initiation is enabled, the operation re-starts at the beginning of the Trigger Model.

When :CONfigure is executed, the instrument goes into the "one-shot" measurement mode. See :CONFigure for more details.

When :READ? is executed, its operations will then be performed. In general, another :ABORt is performed, then an :INITiate, and finally a :FETCh? to acquire the reading. See :READ? for more details.

13
FORMat and Miscellaneous SYSTem Commands

- **FORMat commands** — Covers the SCPI commands to configure the format that readings are sent over the bus.
- **Miscellaneous SYSTem commands** — Covers miscellaneous SYSTem commands.

FORMat commands

The commands in this subsystem are used to select the format for transferring data, Table 13-1, over the bus.

Table 13-1
SCPI commands — data format

Command	Description	Default	Ref
:FORMat			
[:DATA] <type>[,<length>]	Specify data format; ASCii, SREal, REAL, 32, DREal, or REAL, 64.	ASCii	A
:ELEMents <item list>	Specify data elements; READing, UNITs, TSTamp, RNUMber, CHANnel, LIMits.	All 3	B
:BORDer <name>	Specify byte order; NORMal or SWAPped.	(see Note)	C

Note: *RST default is NORMal. SYSTem:PRESet default is SWAPped.

FORMat[:DATA] <type>[,<length>]

Parameters

ASCii	= ASCII format
SREal	= Binary IEEE-754 single precision format
REAL, 32	= Binary IEEE-754 single precision format
DREal	= Binary IEEE-754 double precision format
REAL, 64	= Binary IEEE-754 double precision format

NOTE *<length> is not used for the ASCii, SREal, or DREal parameters.*

The response to READ?, FETCh?, MEASure?, TRACe:DATA?, CALC1:DATA?, or CALC2:DATA? over the GPIB can be returned in either the ASCii or binary format. All other queries are returned in ASCii, regardless of the selected format. Over the RS-232 interface, only the ASCII format is allowed.

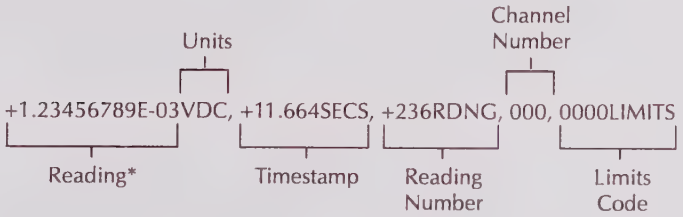
NOTE *Regardless of which data format for output strings is selected, the instrument will only respond to input commands using the ASCII format.*

ASCII data format

The ASCII data format is in a direct readable form for the operator. Most programming languages easily convert ASCII mantissa and exponent to other formats. However, some speed is compromised to accommodate the conversion. Figure 13-1 shows an example ASCII string that includes all the data elements. See :ELEMents for information on the data elements.

Figure 13-1 also shows the byte order of the data string. Data elements not specified by the :ELEMents command are simply not included in the string.

Figure 13-1
ASCII data format



Units:

VDC	=	DC Volts	HZ	=	Frequency
VAC	=	AC Volts	SECS	=	Period
ADC	=	DC Current	C	=	Temperature in °C
AAC	=	AC Current	F	=	Temperature in °F
OHM	=	2-Wire Resistance or Continuity	K	=	Temperature in °K
OHM4W	=	4-Wire Resistance			

*An overflow reading is displayed as +9.9E37 with no limits.

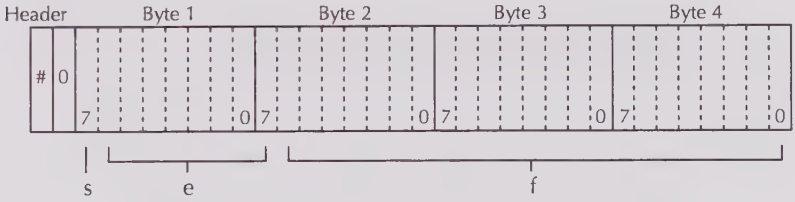
IEEE-754 single precision format

REAL, 32, or SREal will select the binary IEEE-754 single precision data format. Figure 13-2A shows the normal byte order format for each data element. For example, if three data elements are selected, the data string for each reading conversion is made up of three 4-byte data blocks. Note that the data string for each reading conversion is preceded by a 2-byte header that is the binary equivalent of an ASCII # sign and 0. Figure 13-2 does not show the byte for the terminator that is attached to the end of each data string. Note that the byte order of the data string can be sent in reverse order (see :BORDer).

REAL, 64, or DREal selects the binary IEEE754 double precision data format and is shown in Figure 13-2B (normal byte order shown). This format is similar to the single precision format except that it is 64 bits long.

Figure 13-2
IEEE-754 data formats

A) Single precision data format (32 data bits)

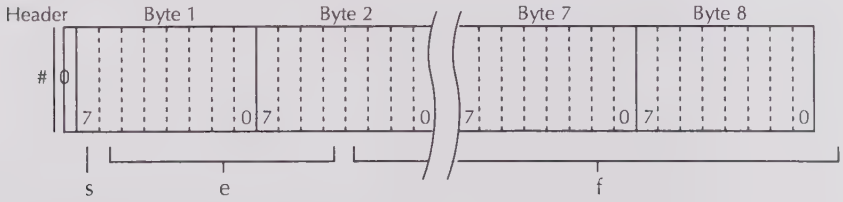


s = sign bit (0 = positive, 1 = negative)
e = exponent bits (8)
f = fraction bits (23)

Normal byte order shown. For swapped byte order, bytes sent in reverse order: Header, Byte 4, Byte 3, Byte 2, Byte 1.

The Header is only sent once for each measurement conversion.

B) Double precision data format (64 data bits)



Bytes 3, 4, 5, and 6 not shown.

s = sign bit (0 = positive, 1 = negative)
e = exponent bits (11)
f = fraction bits (52)

Normal byte order shown. For swapped byte order, bytes sent in reverse order: Header, Byte 8, Byte 7 -- Byte 1.

The Header is only sent once for each measurement conversion.

FORMat:ELEMents <item list>

Parameters

READing	= DMM reading
UNITs	= Units
TSTamp	= Timestamp
RNUMber	= Reading number
CHANnel	= Channel number
LIMits	= Limits reading

The specified elements are included in the data string in response to :FETCh?, :READ?, :MEASure?, and :TRACe:DATA?. Note that each element in the item list must be separated by a comma (i.e. send "FORMat:ELEMents READing, UNITs, TSTamp, RNUMber, CHANnel, LIMits" to include all elements in the data string. The elements for the ASCii format are shown in Figure 13-1.

An overflow reading is returned as +9.9E37. When a specified data element has invalid data associated with it, NAN (Not A Number) will be the response. NAN is returned as +9.9E37.

Timestamp — Timestamp references the returned data string to a point in time. There are two timestamps: relative and real-time clock. The following command selects the timestamp:

```
SYSTem:TSTamp:TYPE <name>      ' Select timestamp type; RELative or RTCL.
```

NOTE *The real-time clock timestamp can only be returned for the ASCII data format. For the binary formats, timestamp will not be sent with the real-time clock selected.*

The relative timestamp operates as a timer that starts at zero seconds when the instrument is turned on, or when the relative timestamp is reset (SYSTem:TSTamp:RELative:RESet). After 99,999.99 seconds, the timer resets back to zero and starts over.

For buffer readings recalled from the front panel, the relative timestamp is referenced to the first reading stored in the buffer (absolute format) which is timestamped at 0 seconds, and to the time between each stored reading (delta format). For remote programming, you can only return the absolute or delta timestamp. The following command is used to select relative timestamp format for the buffer:

```
TRACe:TSTamp:FORMat            ' Select timestamp format; ABSolute or DELTa.
```

Reading number — The reading counter starts at zero when the Model 2700 is turned on. When returning buffer readings using TRACe:DATA?, each reading will be referenced to the first reading, which is #0. The following command will reset the counter:

```
SYSTem:RNUMber:RESet.
```

Channel number — The channel number indicates the switching module channel for the reading. Channel number 000 indicates that no channel was closed.

Limits — For the ASCII data format, limit test results are returned as a 4-bit binary number "abcd" where:

a = High limit 2
b = Low limit 2
c = High limit 1
d = Low limit 1

A "0" indicates that the limit has passed, while a "1" indicates that the limit has failed.

For the binary data formats, the limits information must be decoded from the returned value (0 to 15). Convert the value to its binary equivalent for "abcd" where "d" is the LSD and "a" is the MSD. For example, the value 10 converted to its binary equivalent is1010. That means High Limit 2 and High Limit 1 have failed.

FORMat:BORDer <name>

Parameters

NORMal	= Normal byte order for IEEE-754 binary format
SWAPped	= Reverse byte order for IEEE-754 binary format

For normal byte order, the data format for each element is sent as follows:

Byte 1	Byte 2	Byte 3	Byte 4	(Single precision)
Byte 1	Byte 2	...	Byte 8	(Double precision)

For reverse byte order, data is sent as follows:

Byte 4	Byte 3	Byte 2	Byte 1	(Single precision)
Byte 8	Byte 7	...	Byte 8	(Double precision)

The "#0" header (see Figure 13-2) is not affected by this command. The header is always sent at the beginning of the data string for each measurement conversion.

The ASCII data format can only be sent in the normal byte order. The SWAPped selection is ignored when the ASCII format is selected.

NOTE *The SWAPped byte order must be used when transmitting binary data to any IBM PC.*

Miscellaneous SYSTem commands

SYSTem commands not covered in other sections of the manual are documented here. Table 14-7 lists all SYSTem commands and provides references on where to find more information.

SYSTem:PRESet

Returns the instrument to states optimized for front panel operation. SYSTem:PRESet defaults are listed in the SCPI tables in Section 14.

SYSTem:VERSion

Read the version of the SCPI standard being used by Model 2700. Example response message: 1996.0.

SYSTem:KEY <NRf>

Parameters

1	=	SHIFT key	17	=	-------
2	=	DCV key	18	=	EX TRIG key
3	=	ACV key	19	=	TRIG key
4	=	DCI key	20	=	STORE key
5	=	ACI key	21	=	RECALL key
6	=	Ω2 key	22	=	FILTER key
7	=	Ω4 key	23	=	REL key
8	=	FREQ key	24	=	Cursor left arrow key
9	=	-------	25	=	-------
10	=	-------	26	=	OPEN key
11	=	RANGE up arrow key	27	=	CLOSE key
12	=	AUTO key	28	=	STEP key
13	=	ENTER key	29	=	SCAN key
14	=	RANGE down arrow key	30	=	DIGITS key
15	=	Cursor right arrow key	31	=	RATE key
16	=	TEMP key	32	=	EXIT key

This command is used to simulate front panel key presses. For example, to select the volts measurement function, send the following command to simulate pressing the "DCV" key: SYSTem:KEY 2. The key-press codes are also shown in Figure 13-3.

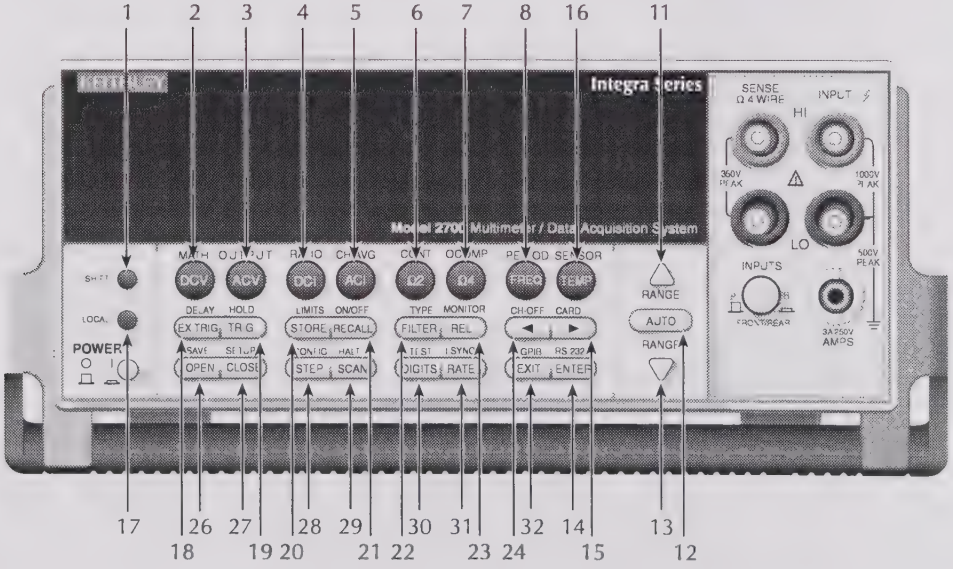
The queue for the :KEY? query command can only hold one key-press. When :KEY? is sent and Model 2700 is addressed to talk, the key-press code number for the last key "pressed" is sent to the computer.

SYSTem:BEEPer[:STATe] <b>

You can disable the beeper for limits and continuity tests. However, when limits or CONT is again selected, the beeper will automatically enable.

Parameters <b> = 0 Disable beeper
= 1 Enable beeper

Figure 13-3
Key-press codes



14
SCPI Reference Tables

Reference tables

Table 14-1 through Table 14-10 summarize the commands for each SCPI subsystem. The following list includes the SCPI subsystem commands and the table number where each command is summarized.

Table 14-1 – CALCulate command summary
Table 14-2 – DISPlay command summary
Table 14-3 – FORMat command summary
Table 14-4 – ROUTe command summary
Table 14-5 – SENSe command summary
Table 14-6 – STATus command summary
Table 14-7 – SYSTem command summary
Table 14-8 – TRACe command summary
Table 14-9 – Trigger command summary
Table 14-10 – UNIT command summary

General notes:

- Brackets ([ ]) are used to denote optional character sets. These optional characters do not have to be included in the program message. Do not use brackets in the program message.
- Angle brackets (< >) are used to indicate parameter type. Do not use angle brackets in the program message.
- The Boolean parameter (<b>) is used to enable or disable an instrument operation. 1 or ON enables the operation, and 0 or OFF disables the operation.
- Upper case characters indicate the short-form version for each command word.
- Default Parameter – Listed parameters are both the *RST and :SYSTem:PRESet defaults, unless noted otherwise. Parameter notes are located at the end of each table.
- Ref – The reference column indicates where to find detailed information on the command(s).
- SCPI – A checkmark (✓) indicates that the command and its parameters are SCPI confirmed. An unmarked command indicates that it is a SCPI command, but does not conform to the SCPI standard set of commands. It is not a recognized command by the SCPI consortium. SCPI confirmed commands that use one or more non-SCPI parameters are explained by notes.

Table 14-1
CALCulate command summary

Command	Description	Default parameter	Ref	SCPI
:CALCulate[1]	Subsystem to control CALC 1:		Sec 4	✓
:FORMat <name> [<, clist>]	Select math format (NONE, MXB, PERCent).	PERCent		✓
:FORMat? [<clist>]	Query math format.			✓
:KMATh	Path to configure math calculations:			
:MMFactor <NRf> [, <clist>]	Set "m" factor for mx+b (-100e6 to 100e6).[1]	1		
:MA1Factor <NRf> [, <clist>]	Set "m" factor for mx+b (-100e6 to 100e6).[1]	1		
:MMFactor? [<clist>]	Query "m" factor. [1]			
:MA1Factor? [<clist>]	Query "m" factor. [1]			
:MBFactor <NRf> [, <clist>]	Set "b" factor for mx+b (-100e6 to 100e6).[2]	0		
:MA0Factor <NRf> [, <clist>]	Set "b" factor for mx+b (-100e6 to 100e6).[2]	0		
:MBFactor? [<clist>]	Query "b" factor.[2]			
:MA0Factor? [<clist>]	Query "b" factor.[2]			
:MUNits <char>	Specify units for mx+b reading.[3]	'X'		
:MUNits?	Query "mx+b" units.			
:PERCent <NRf> [, <clist>]	Set target value for PERCent calculation (-4294967295 to +4294967295).	1		
:ACQuire	Use input signal as target value.			
:PERCent? [<clist>]	Query percent.			
:STATe <b> [, <clist>]	Enable or disable kmath calculation.	(Note 4)		✓
:STATe? [< clist>]	Query state of kmath function.			✓
:DATA?	Read result of kmath calculation.			✓
:CALCulate2	Subsystem to control CALC 2:		Sec 5	✓
:FORMat <name>	Select math format: (MEAN, SDEViation, MAXimum, MINimum, PKPK or NONE).	NONE		✓
:FORMat?	Query math format.			✓
:STATe <b>	Enable or disable calculation.	(Note 4)		✓
:STATe?	Query state of math function.			✓
:IMMediate	Recalculate raw input data in buffer.			✓
:IMMediate?	Perform calculation and read result.			✓
:DATA?	Read math result of CALC 2.			✓
:CALCulate3	Subsystem to control CALC 3 (limit test):		Sec 8	✓
:MLIMit	Path for master limit command:			
:LATCched <b>	Enable or disable master limit latch.	OFF		
:OUTPut	Path for limit output commands:			
[:STATe] <b>	Enable or disable limit outputs.	OFF		
[:STATe]?	Query state of limit outputs.			

Table 14-1 (Continued)
CALCulate command summary

Command	Description	Default parameter	Ref	SCPI
:PULSe	Path to control limit output pulsing:			
[:STATe] <b>	Enable or disable limit output pulsing.	OFF		
[:STATe]?	Query state of limit output pulsing.			
:TIME <NRf>	Set output pulse time in sec (0.001 to 999999.999).	0.002		
:TIME?	Query output pulse time.			
:LSENse <name>	Set logic sense of all limit lines (AHIGh or ALOW).	AHIGh		
:LSENse?	Query logic sense of limit lines.			
:LIMit1	Path to control LIMIT 1 test:			✓
:UPPer	Path to configure upper limit:			✓
[:DATA] <n> [, <clist>]	Set upper limit (-4294967295 to +4294967295).	1		✓
[:DATA]? [<clist>]	Query upper limit.			✓
:LOWer	Path to configure lower limit:			✓
[:DATA] <n> [, <clist>]	Set lower limit (-4294967295 to +4294967295).	-1		✓
[:DATA]? [<clist>]	Query lower limit.			✓
:STATe <b> [, <clist>]	Enable or disable limit test.	OFF		✓
:STATe? [<clist>]	Query state of limit test.			✓
:FAIL?	Query test result (1 = failing).			✓
:CLEAR	Path to clear events:			✓
[:IMMediate]	Clear high and low events.			✓
:AUTO <b>	Enable or disable auto-clear.	ON		✓
:AUTO?	Query auto-clear.			✓
:LIMit2	Path to control LIMIT 2 test:			✓
:UPPer	Path to configure upper limit:			✓
[:DATA] <n> [, <clist>]	Set upper limit (-4294967295 to +4294967295).	2		✓
[:DATA]? [<clist>]	Query upper limit.			✓
:LOWer	Path to configure lower limit:			✓
[:DATA] <n> [, <clist>]	Set lower limit (-4294967295 to +4294967295).	-2		✓
[:DATA]? [<clist>]	Query lower limit.			✓
:STATe <b> [, <clist>]	Enable or disable limit test.	OFF		✓
:STATe? [<clist>]	Query state of limit test.			✓
:FAIL?	Query test result (1 = failing).			✓

Table 14-1 (Continued)
CALCulate command summary

Command	Description	Default parameter	Ref	SCPI
:CLEAR	Path to clear events:			✓
[:IMMediate]	Clear high and low events.			✓
:AUTO <b>	Enable or disable auto-clear.	ON		✓
:AUTO?	Query auto-clear.			✓

Notes:
1. The :MMFactor and :MA1Factor commands perform the same operations.
2. The :MBFactor and :MA0Factor commands perform the same operations.
3. For mX+b units, <char> = one character; 'A' through 'Z', degrees symbol ('°') or ohms symbol ('Ω').
4. ON is the *RST default parameter, and OFF is the :SYSTem:PRESet default.

Table 14-2
DISPlay command summary

Command	Description	Default parameter	Ref	SCPI
:DISPlay		(see Note)	Sec 1	
[:WINDow[1]]				✓
:TEXT	Path to control user text messages.			✓
:DATA <a>	Define ASCII message "a" (up to 12 characters).	(none)		✓
:DATA?	Query text message.			✓
:STATe <b>	Enable or disable message mode.	OFF		✓
:STATe?	Query text message state.			✓
:ENABle <b>	Enable or disable the front panel display.	OFF		✓
:ENABle?	Query state of the display.			✓

Note: *RST and :SYSTem:PRESet have no effect on commands in this subsystem. The listed defaults are power-on defaults.

Table 14-3
FORMat command summary

Command	Description	Default parameter	Ref	SCPI
:FORMat			Sec 13	
[:DATA] <type>[,<length>]	Select data format (ASCii, SREal or DREal).	ASCii		
[:DATA]?	Query data format.			✓
:ELEMents <item list>	Specify data elements (READing, CHANnel, UNITs, RNUMber, TSTamp, and LIMits).	(see Note)		✓
:ELEMents?	Query data elements.			✓
:BORDer <name>	Select binary byte order (NORMal or SWAPped).	SWAPped		✓
:BORDer?	Query byte order.			✓

Note: The :SYSTem:PRESet and *RST default is READ, UNIT, RNUM, and TST.

Table 14-4
ROUTe command summary

Command	Description	Default parameter	Ref	SCPI
:ROUTe				
:MONitor <clist>	Specify one channel to be monitored.		Sec 6	
:STATe <b>	Enable or disable channel monitoring.	OFF		
:STATe?	Query state of channel monitoring.			
:DATA?	Returns the most recent monitor reading.			
:POINts <NRf>	For a monitor scan, specify number of channels to scan (2 to 55000)	(Note 1)		
:POINts?	For a monitor scan, query number of channels to scan.			
:MONitor?	Query the channel to be monitored.			
:CLOSe <clist>	Close the one specified channel (all others will open).		Sec 2	
:STATe? <clist>	Query closed channels in specified list (1 = closed).			
:ACONfigure <b>	Enable or disable auto-configure.	(Note 2)		
:ACONfigure?	Query state of auto-configure.			
:CLOSe?	Returns a <clist> of closed channels.			
:OPEN:ALL	Open all channels.		Sec 2	
:MULTiple	Path to control multiple channels:		Sec 2	
:OPEN <clist>	Open channel(s) specified in list. Unlisted channels not affected.			
:CLOSe <clist>	Close channel(s) specified in list. Unlisted channels not affected.			
:STATe? <clist>	Query closed channels in specified list (1 = closed).			✓
:CLOSe?	Return list of all closed channels.			
:SCAN <clist>			Sec 6	
[:INTernal] <clist>	Specify list of channels to be scanned.			
[:INTernal]	Query scan list.			
:TSOurce <list>	Select trigger source to start the scan (IMMediate, or HLIMit1, HLIMit2, LLIMit1, and LLIMit2).	IMM		
:TSOurce?	Query trigger source for scan.			
:NVOLatile <b>	Enable or disable nonvolatile memory for scanning (autoscan).	(Note 2)		
:NVOLatile?	Query nonvolatile memory setting for scan/buffer.			
:LSELect <name>	Enable (INTernal) or disable (NONE) scan.	NONE		
:LSELect?	Query state of scan.			

Notes:
1. Default value depends on which switching module is installed.
2. Not affected by *RST and :SYSTem:PRESet. Front panel factory default is OFF.

Table 14-5
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
[:SENSe[1]]				
:FUNCtion <name> [, <clist>]	Select measurement function: 'VOLTage:[DC]', 'VOLTage :AC', 'CURRent:DC', 'CURRent:AC', 'RESistance', 'FRESistance', 'TEMPerature', 'FREQuency', 'PERiod', or 'CONTinuity'.	'VOLT:DC'	Sec 2	✓
:FUNCtion? [<clist>]	Query function.			✓
:DATA?	Return the last instrument reading.		Sec 2	✓
:HOLD	Path to control Hold feature:		Sec 7	
:WINDow <NRf>	Set Hold window in % (0.01 to 20).	1		
:WINDow?	Query Hold window.			
:COUNt <NRf>	Set Hold count; 2 to 100.	5		
:COUNt?	Query Hold count.			
:STATe <NRf>	Enable or disable Hold.	OFF		
:STATe?	Query state of Hold.			
:CAVerage <b> [, <clist>]	Enable or disable channel average.	OFF	Sec 4	
:DELay <NRf> [, <clist>]	Set delay between the two measurements in seconds (0 to 999999.999).[1]	0.5		
:DELay? [<clist>]	Query delay.			
:CAVerage? [, <clist>]	Query state of channel average.			
:RATio <b> [, <clist>]	Enable or disable channel ratio.	OFF	Sec 4	
:DELay <NRf> [, <clist>]	Set delay between the two measurements in seconds (0 to 999999.999).[1]	0.5		
:DELay? [<clist>]	Query delay.			
:RATio? [<clist>]	Query state of channel ratio.			
:TOTalize	Path to configure the Model 7706 Totalizer:			
:TYPE <name> [, <clist>]	Select Totatlizer type; READ or RRESet (read and reset).	READ	App	
:TYPE? [<clist>]	Query Totalizer type.			
:EDGE <name> [, <clist>]	Select input signal edge (RISing or FALLing).	RISING		
:EDGE? [<clist>]	Query input signal edge.			
:DATA?	Read the Totalizer count (reset if RRESet selected).			
:VOLTage[:DC]	Path to configure DC voltage.		Sec 2	✓
:APERture <NRf> [, <clist>]	Set integration rate in seconds (60Hz; 1.67e-4 to 1, 50Hz; 2e-4 to 1).	(Note 2)	Sec 3	
:APERture? [<clist>]	Query aperature integration rate.			
:NPLCycles <n> [, <clist>]	Set integration rate in line cycles (60Hz; 0.01 to 60, 50Hz; 0.01 to 50).	5.0	Sec 3	✓
:NPLCycles? [<clist>]	Query line cycle integration rate.			✓

Table 14-5 (Continued)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:RANGe	Path to set measurement range:		Sec 3	✓
[:UPPer] <n> [, <clist>]	Select range (0 to 1010).	1000		✓
[:UPPer]? [<clist>]	Query range.			✓
:AUTO <b> [, <clist>]	Enable or disable auto range.	ON		✓
:AUTO? [<clist>]	Query state of auto range.			✓
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	7	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n> [, <clist>]	Specify reference (-1010 to 1010).	0	Sec 4	✓
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		✓
:STATe? [<clist>]	Query state of reference.			✓
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			✓
:AVERage	Path to configure and control filter:		Sec 3	
:TCONtrol <name>	Select filter type: (MOVing or REPeat).	(Note 3)		
:TCONtrol?	Query filter type.			
:WINDow <NRf>	Set filter window in % of range (0 to 10).	0.1		
:WINDow?	Query filter window.			
:COUNt <n> [, <clist>]	Specify filter count (1 to 100).	10		
:COUNt? [<clist>]	Query filter count.			
[:STATe] <b> [, <clist>]	Enable or disable filter.	(Note 4)		
[:STATe]? [<clist>]	Query state of digital filter.			
:IDIVider <b>	Enable or disable 10MΩ input divider.	OFF	Sec 2	
:IDIVider?	Query state of input divider.			
:VOLTage:AC	Path to configure AC voltage.		Sec 2	✓
:APERture <NRf> [, <clist>]	Set integration rate in seconds (60Hz; 1.67e-4 to 1, 50Hz; 2e-4 to 1).	(Note 2)	Sec 3	
:APERture? [<clist>]	Query aperature integration rate.			
:NPLCycles <n>[, <clist>]	Set integration rate in line cycles (60Hz; 0.01 to 60, 50Hz; 0.01 to 50).	1.0	Sec 3	✓
:NPLCycles? [<clist>]	Query line cycle integration rate.			✓
:RANGe	Path to set measurement range:		Sec 3	✓
[:UPPer] <n> [, <clist>]	Select range (0 to 757.5).	750		✓
[:UPPer]? [<clist>]	Query range.			✓
:AUTO <b> [, <clist>]	Enable or disable auto range.	ON		✓
:AUTO? [<clist>]	Query state of auto range.			✓
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	6	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n> [, <clist>]	Specify reference (-757.5 to 757.5).	0	Sec 4	✓
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		✓
:STATe? [<clist>]	Query state of reference.			✓
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			✓

Table 14-5 (Continued)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:AVERage	Path to configure and control filter:		Sec 3	
:TCONtrol <name>	Select filter type: (MOVing or REPeat).	(Note 3)		
:TCONtrol?	Query filter type.			
:WINDow <NRf>	Set filter window in % of range (0 to 10).	0.1		
:WINDow?	Query filter window.			
:COUNt <n> [, <clist>]	Specify filter count (1 to 100).	10		
:COUNt? [<clist>]	Query filter count.			
[:STATe] <b> [, <clist>]	Enable or disable filter.	(Note 4)		
[:STATe]? [<clist>]	Query state of digital filter.			
:DETector	Path to set bandwidth:		Sec 2	
:BANDwidth <NRf> [, <clist>]	Set AC detector bandwidth in Hertz (3 to 3e5).	30		
:BANDwidth? [<clist>]	Query bandwidth.			
:CURRent:DC	Path to configure DC current.		Sec 2	✓
:APERture <NRf> [, <clist>]	Set integration rate in seconds (60Hz; 1.67e-4 to 1, 50Hz; 2e-4 to 1).	(Note 2)	Sec 3	
:APERture? [<clist>]	Query aperature integration rate.			
:NPLCycles <n>[, <clist>]	Set integration rate in line cycles (60Hz; 0.01 to 60, 50Hz; 0.01 to 50).	1.0	Sec 3	✓
:NPLCycles? [<clist>]	Query line cycle integration rate.			✓
:RANGe	Path to set measurement range:		Sec 3	✓
[:UPPer] <n> [, <clist>]	Select range (0 to 3.1).	3		✓
[:UPPer]? [<clist>]	Query range.			✓
:AUTO <b> [, <clist>]	Enable or disable auto range.	ON		✓
:AUTO? [<clist>]	Query state of auto range.			✓
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	7	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n> [, <clist>]	Specify reference (-3.1 to 3.1).	0	Sec 4	✓
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		✓
:STATe? [<clist>]	Query state of reference.			✓
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			✓
:AVERage	Path to configure and control filter:		Sec 3	
:TCONtrol <name>	Select filter type: (MOVing or REPeat).	(Note 3)		
:TCONtrol?	Query filter type.			
:WINDow <NRf>	Set filter window in % of range (0 to 10).	0.1		
:WINDow?	Query filter window.			
:COUNt <n> [, <clist>]	Specify filter count (1 to 100).	10		
:COUNt? [<clist>]	Query filter count.			
[:STATe] <b> [, <clist>]	Enable or disable filter.	(Note 4)		
[:STATe]? [<clist>]	Query state of digital filter.			

Table 14-5 (Continued)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:CURRent:AC	Path to configure AC current.		Sec 2	✓
:APERture <NRf> [, <clist>]	Set integration rate in seconds (60Hz; 1.67e-4 to 1, 50Hz; 2e-4 to 1).	(Note 2)	Sec 3	
:APERture? [<clist>]	Query aperature integration rate.			
:NPLCycles <n>[, <clist>]	Set integration rate in line cycles (60Hz; 0.01 to 60, 50Hz; 0.01 to 50).	1.0	Sec 3	✓
:NPLCycles? [<clist>]	Query line cycle integration rate.			✓
:RANGe	Path to set measurement range:		Sec 3	✓
[:UPPer] <n>[, <clist>]	Select range (0 to 3.1).	3		✓
[:UPPer]? [<clist>]	Query range.			✓
:AUTO <b> [, <clist>]	Enable or disable auto range.	ON		✓
:AUTO? [<clist>]	Query state of auto range.			✓
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	6	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n>[, <clist>]	Specify reference (-3.1 to 3.1).	0	Sec 4	✓
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		✓
:STATe? [<clist>]	Query state of reference.			✓
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			✓
:AVERage	Path to configure and control filter:		Sec 3	
:TCONtrol <name>	Select filter type: (MOVing or REPeat).	(Note 3)		
:TCONtrol?	Query filter type.			
:WINDow <NRf>	Set filter window in % of range (0 to 10).	0.1		
:WINDow?	Query filter window.			
:COUNt <n> [, <clist>]	Specify filter count (1 to 100).	10		
:COUNt? [<clist>]	Query filter count.			
[:STATe] <b> [, <clist>]	Enable or disable filter.	(Note 4)		
[:STATe]? [<clist>]	Query state of digital filter.			
:DETector	Path to set bandwidth:		Sec 2	
:BANDwidth <NRf> [, <clist>]	Set AC detector bandwidth in Hertz (3 to 3e5).	30		
:BANDwidth? [<clist>]	Query bandwidth.			
:RESistance	Path to configure resistance.		Sec 2	✓
:APERture <NRf> [, <clist>]	Set integration rate in seconds (60Hz; 1.67e-4 to 1, 50Hz; 2e-4 to 1).	(Note 2)	Sec 3	
:APERture? [<clist>]	Query aperature integration rate.			
:NPLCycles <n>[, <clist>]	Set integration rate in line cycles (60Hz; 0.01 to 60, 50Hz; 0.01 to 50).	1.0	Sec 3	✓
:NPLCycles? [<clist>]	Query line cycle integration rate.			✓
:RANGe	Path to set measurement range:		Sec 3	✓
[:UPPer] <n> [, <clist>]	Select range (0 to 120e6).	100e6		✓
[:UPPer]? [<clist>]	Query range.			✓

Table 14-5 (Continued)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:AUTO <b> [, <clist>]	Enable or disable auto range.	ON		✓
:AUTO? [<clist>]	Query state of auto range.			✓
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	7	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n> [, <clist>]	Specify reference (0 to 120e6).	0	Sec 4	✓
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		✓
:STATe? [<clist>]	Query state of reference.			✓
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			✓
:AVERage	Path to configure and control filter:		Sec 3	
:TCONtrol <name>	Select filter type: (MOVing or REPeat).	(Note 3)		
:TCONtrol?	Query filter type.			
:WINDow <NRf>	Set filter window in % of range (0 to 10).	0.1		
:WINDow?	Query filter window.			
:COUNt <n> [, <clist>]	Specify filter count (1 to 100).	10		
:COUNt? [<clist>]	Query filter count.			
[:STATe] <b> [, <clist>]	Enable or disable filter.	(Note 4)		
[:STATe]? [<clist>]	Query state of digital filter.			
:FRESistance	Path to configure four-wire resistance.		Sec 2	✓
:APERture <NRf> [, <clist>]	Set integration rate in seconds (60Hz; 1.67e-4 to 1, 50Hz; 2e-4 to 1).	(Note 2)	Sec 3	
:APERture? [<clist>]	Query aperature integration rate.			
:NPLCycles <n>[, <clist>]	Set integration rate in line cycles (60Hz; 0.01 to 60, 50Hz; 0.01 to 50).	1.0	Sec 3	✓
:NPLCycles? [<clist>]	Query line cycle integration rate.			✓
:RANGe	Path to set measurement range:		Sec 3	✓
[:UPPer] <n> [, <clist>]	Select range (0 to 120e6).	100e6		✓
[:UPPer]? [<clist>]	Query range.			✓
:AUTO <b> [, <clist>]	Enable or disable auto range.	ON		✓
:AUTO? [<clist>]	Query state of auto range.			✓
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	7	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n> [, <clist>]	Specify reference (0 to 120e6).	0	Sec 4	✓
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		✓
:STATe? [<clist>]	Query state of reference.			✓
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			✓
:AVERage	Path to configure and control filter:		Sec 3	
:TCONtrol <name>	Select filter type: (MOVing or REPeat).	(Note 3)		
:TCONtrol?	Query filter type.			
:WINDow <NRf>	Set filter window in % of range (0 to 10).	0.1		
:WINDow?	Query filter window.			

Table 14-5 (Continued)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:COUNt <n> [, <clist>]	Specify filter count (1 to 100).	10		
:COUNt? [<clist>]	Query filter count.			
[:STATe] <b> [, <clist>]	Enable or disable filter.	(Note 4)		
[:STATe]? [<clist>]	Query state of digital filter.			
:OCOMpensated <b> [, <clist>]	Enable or disable offset compensation.	OFF	Sec 2	
:OCOMpensated? [<clist>]	Query state of offset compensation.			
:TEMPerature	Path to configure temperature:		Sec 2	✓
:APERture <NRf> [, <clist>]	Set integration rate in seconds (60Hz; 1.67e-4 to 1, 50Hz; 2e-4 to 1).	(Note 2)	Sec 3	
:APERture? [<clist>]	Query aperature integration rate.			
:NPLCycles <n>[, <clist>]	Set integration rate in line cycles (60Hz; 0.01 to 60, 50Hz; 0.01 to 50).	1.0	Sec 3	✓
:NPLCycles?	Query line cycle integration rate.			✓
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	6	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n> [, <clist>]	Specify reference in °C (-200 to 1820).	0	Sec 4	✓
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		✓
:STATe? [<clist>]	Query state of reference.			✓
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			✓
:AVERage	Path to configure and control filter:		Sec 3	
:TCONtrol <name>	Select filter type: (MOVing or REPeat).	(Note 3)		
:TCONtrol?	Query filter type.			
:WINDow <NRf>	Set filter window in % of range (0 to 10).	0.1		
:WINDow?	Query filter window.			
:COUNt <n> [, <clist>]	Specify filter count (1 to 100).	10		
:COUNt? [<clist>]	Query filter count.			
[:STATe] <b> [, <clist>]	Enable or disable filter.	(Note 4)		
[:STATe]? [<clist>]	Query state of digital filter.			
:TRANsducer <name> [, <clist>]	Select temperature transducer (TCouple, FRTD or THERmister).		Sec 2	
:TRANsducer? [<clist>]	Query transducer type.	TCouple		
:TCouple	Path to configure thermocouple:[5]		Sec 2	
:TYPE <type> [, <clist>]	Select T/C type (J, K, T, E, R, S, B, N).	K		
:TYPE? [<clist>]	Query T/C type.			
:ODETect <b>	Enable or disable T/C open detector.	OFF		
:ODETect?	Query state of T/C open detector.			
:RJUNction	Path to configure reference junction:[5]			
:RSELect <name> [, <clist>]	Select reference junction (SIMulated, INTernal or EXTernal).	SIM		
:RSELect? [<clist>]	Query reference junction.			

Table 14-5 (Continued)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:SIMulated <n> [, <clist>]	Set simulated reference temperature; 0 to 50 (°C), 32 to 122 (°F), or 273 to 323 (K).	23		
:SIMulated? [<clist>]	Query simulated reference temperature.			
:THERmistor	Path to configure thermister:		Sec 2	
[:TYPE] <NRf> [, <clist>]	Set thermister type in ohms (1950 to 10050).	5000		
[:TYPE]? [<clist>]	Query thermister type.			
:FRTD	Path to configure 4-wire RTD;		Sec 2	
:TYPE <name> [, <clist>]	Select FRTD type (PT100, D100, F100, PT3916, PT385, or USER.	PT100		
:TYPE? [<clist>]	Query FRTD type.			
:RZERo <NRf> [, <clist>]	Specify constant for USER type (0 to 10000).	100		
:RZERo? [<clist>]	Query rzero.			
:ALPHa <NRf>[, <clist>]	Specify constant for USER type (0 to 0.01).	0.00385		
:ALPHa? [<clist>]	Query alpha.			
:BETA <NRf> [, <clist>]	Specify constant for USER type (0 to 1.00).	0.111		
:BETA? [<clist>]	Query beta.			
:DELTa <NRf> [, <clist>]	Specify constant for USER type (0 to 5.00).	1.507		
:DELTa? [<clist>]	Query delta.			
:FREQuency	Path to configure frequency.		Sec 2	
:APERture <NRf> [, <clist>]	Sets gate time for frequency measurements in seconds (0.01 to 1.0).	1.0	Sec 3	
:APERture? [<clist>]	Query frequency gate time.			
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	7	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n> [, <clist>]	Specify reference (0 to 1.5e7)	0	Sec 4	
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		
:STATe? [<clist>]	Query state of reference.			
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			
:THReshold	Path to select the threshold voltage range:		Sec 2	✓
:VOLTage				✓
:RANGe <n>	Select threshold range (0 to 1010).	10		
:RANGe?	Query threshold range.			

Table 14-5 (Continued)
SENSe command summary

Command	Description	Default parameter	Ref	SCPI
:PERiod	Path to configure period:		Sec 2	
:APERture <NRf> [, <clist>]	Sets gate time for period measurements in seconds (0.01 to 1.0).	1.0	Sec 3	
:APERture? [<clist>]	Query period gate time.			
:DIGits <n> [, <clist>]	Specify measurement resolution (4 to 7).	7	Sec 3	
:DIGits? [<clist>]	Query resolution.			
:REFerence <n> [, <clist>]	Specify reference (0 to 1).	0	Sec 4	
:STATe <b> [, <clist>]	Enable or disable reference.	OFF		
:STATe? [<clist>]	Query state of reference.			
:ACQuire	Use input signal as reference.			
:REFerence? [<clist>]	Query reference value.			
:THReshold	Path to select the threshold voltage range:		Sec 2	
:VOLTage				
:RANGe <n>	Select threshold range (0 to 1010).	10		
:RANGe?	Query threshold range.			
:CONTinuity	Path to configure continuity test:		Sec 2	
:THReshold <NRf>	Set threshold resistance in ohms (1 to 1000).	10		
:THReshold?	Query threshold resistance.			

Notes:

1. CAVerage:DELay and RATio:DELay are coupled. Changing the delay for channel average also changes the delay for channel ratio, and vice versa.
2. For 60Hz line power, the default for aperture is 16.67msec. For 50Hz, the default is 20msec.
3. REPeat is the *RST default and MOVing is the :SYSTem:PRESet default. From the front panel, the factory default is MOVing.
4. OFF is the *RST default, and ON is the :SYTem:PRESet default.
5. The following commands can instead be used to select the reference junction and set the simulated reference temperature:

:TEMPerature:RJUNction:RSELect <name> [, <clist>]	Select reference junction; SIMulated, INTernal, or EXTernal.
:TEMPerature:RJUNction:RSELect? [<clist>]	Query reference junction.
:TEMPerature:RJUNction:SIMulated <n> [, <clist>]	Set simulated reference temperature; 0 to 50 (°C), 32 to 122 (°F), or 273 to 323 (K).
:TEMPerature:RJUNction:SIMulated? [<clist>]	Query simulated reference temperature.

Table 14-6
STATus command summary

Command	Description	Default parameter	Ref	SCPI
:STATus		(Note 1)	Sec 10	✓
:MEASurement	Path to control measurement event registers:			
[:EVENt]?	Read the event register.	(Note 2)		
:ENABle <NRf>	Program the enable register.	(Note 3)		
:ENABle?	Read the enable register.			
:CONDition?	Read the condition register.			
:OPERation	Path to control operation status registers:			✓
[:EVENt]?	Read the event register.	(Note 2)		✓
:ENABle <NRf>	Program the enable register.	(Note 3)		✓
:ENABle?	Read the enable register.			✓
:CONDition?	Read the condition register.			✓
:QUEStionable	Path to control questionable status registers:			✓
[:EVENt]?	Read the event register.	(Note 2)		✓
:ENABle <NRf>	Program the enable register.	(Note 3)		✓
:ENABle?	Read the enable register.			✓
:CONDition?	Read the condition register.			✓
:PRESet	Return status registers to default states.			✓
:QUEue	Path to access error queue:			✓
[:NEXT]?	Read the most recent error message.	(Note 4)		✓
:ENABle <list>	Specify error and status messages for queue.	(Note 5)		✓
:ENABle?	Read the enabled messages.			✓
:DISable <list>	Specify messages not to be placed in queue.	(Note 5)		
:DISable?	Read the disabled messages.			
:CLEar	Clears all messages from Error Queue.			

Notes:

1. Commands in this subsystem are not affected by *RST and :SYSTem:PRESet. The effects of cycling power, *CLS and :STATus:PRESet are explained by the following notes.
2. Event Registers: Power-up and *CLS – Clears all bits of the registers.
   :STATus:PRESet – No effect.
3. Enable Registers: Power-up and :STATus:PRESet – Clears all bits of the registers.
   *CLS – No effect.
4. Error Queue: Power-up and *CLS – Clears the Error Queue.
   :STATus:PRESet – No effect.
5. Enable/Disable Error Queue Messages: Power-up – Clears list of messages.
   *CLS and :STATus:PRESet – No effect.

Table 14-7
SYSTem command summary

Command	Description	Default parameter	Ref	SCPI
:SYSTem				
:PRESet	Return to :SYST:PRES defaults.		Sec 13	✓
:POSetup <name>	Select power-on setup: (RST, PRESet, SAV0, SAV1, SAV2, or SAV3).		Sec 1	
:POSetup?	Query power-on setup.			
:FRSWitch?	Query INPUTS switch (0=rear, 1=front).		Sec 1	
:BEEPer	Path to control beeper.		Sec 13	
[:STATe] <b>	Enable or disable beeper.	ON		✓
[:STATe]?	Query state of beeper.			✓
:KCLick <b>	Turn the keyclick on/off.	ON	Sec 1	
:KCLick?	Query the keyclick status.			
:KEY <NRf>	Simulate key-press (1 to 31; see Figure 13-3).		Sec 13	✓
:KEY?	Query the last "pressed" key.			✓
:AZERo	Path to set up autozero.		Sec 2	
:STATe <b>	Enable or disable autozero.	ON		
:STATe?	Query autozero.			
:LSYNc	Path to control line synchronization:		Sec 2	
[:STATe] <b>	Enable or disable line-sync.	OFF		
[:STATe]?	Query state of line-sync.			
:LFRequency?	Query power line frequency.		Sec 1	
:PCARd1 <name>	Set up an empty slot 1 as a "psuedocard" (C7700, C7702, C7703, C7705, C7706).		Sec 1	
:PCARd2 <name>	Set up an empty slot 2 as a "psuedocard" (C7700, C7702, C7703, C7705, C7706).		Sec 1	
:CARDx	Path to query switching module in slot x; x=1 or 2.			
:SNUMber?	Request serial number.			
:SWRevision?	Request firmware revision.			
:VMAX?	Request maximum allowable voltage.			
:MUX?	Support multiplexer channels?; 1 = yes, 0 = no.			
:ISOLated?	Support isolated channels?; 1 = yes, 0 = no.			
:TCOMpensated?	Built-in temperature sensors for T/C cold junction?; 1 = yes, 0 = no.			
:VCHannel	Path to query volts/2-wire channels:			
[:STARt]?	Request lowest numbered volts/2-wire channel (usually 1); 0 = voltage measurements not supported.			
:END?	Request highest numbered volts/2-wire channel. 0 = voltage measurements not supported.			

Table 14-7
SYSTem command summary

Command	Description	Default parameter	Ref	SCPI
:ACHannel	Path to query amps channels:			
[:STARt]?	Request lowest numbered amps channel; 0 = amps measurements not supported.			
:END?	Request highest numbered amps channel; 0 = amps measurements not supported.			
:AOUTput	Path to query analog output channels:			
[:STARt]?	Request highest numbered analog output channel; 0 = analog output not supported.			
:END?	Request lowest numbered analog output channel; 0 = analog output not supported.			
:DOUTput	Path to query digital output channels:			
[:STARt]?	Request highest numbered digital output channel; 0 = digital output not supported.			
:END?	Request lowest numbered digital output channel; 0 = digital output not supported.			
:TCHannel?	Query the totalizer channel.			
:TIME <hr, min, sec>	Set system time using 24-hour format.		Sec 5	
:TIME?	Query system time.			
:DATE <yr, mo, day>	Set system date (yr = 1999 or 20xx).		Sec 5	
:DATE?	Query system date.			
:TSTamp	Path to set timestamp:		Sec 5	
:TYPE <name>	Select timestamp type (RELative or RTCLock).	REL		
:TYPE?	Query timestamp type.			
:RELative	Path to reset relative timestamp:			
:RESet	Reset relative timestamp to 0.			
:RNUMber	Path to reset reading number:		Sec 13	
:RESet	Reset reading number. Next reading will be #1.			
:ERRor?	Query (read) Error Queue.	(Note)	Sec 10	✓
:CLEar	Clears messages from the Error Queue.		Sec 10	
:VERSion?	Query rev level of SCPI standard.		Sec 13	✓
:LOCal	Take 2700 out of remote and restore operation of front panel controls (RS-232 only).		Sec 9	
:REMote	Place 2700 in remote (RS-232 only).		Sec 9	
:RWLock	Lockout front panel controls (RS-232 only).		Sec 9	

Note: Power-up and *CLS clears the error queue.
*RST, :SYSTem:PRESet, and :STATus:PRESet has no effect on the error queue.

Table 14-8
TRACe command summary

Command	Description	Default parameter*	Ref	SCPI
:TRACe|:DATA	Use :TRACe or :DATA as root command.		Sec 5	
:CLEar	Path to clear the buffer.			
[:IMMediate]	Clear the buffer.			
:AUTO <b>	Enable or disable buffer auto-clear.	ON		
:AUTO?	Query state of buffer auto-clear.			
:FREE?	Query bytes available and bytes in use.			✓
:POINts <NRf>	Specify size of buffer (2 to 55000).	100		✓
:POINts?	Query buffer size.			✓
:NEXT?	Query buffer location of last stored reading.			
:TSTamp	Path to set timestamp format:			
:FORMat <name>	Select timestamp format (ABSolute or DELTa).	ABS		
:FORMat?	Query timestamp format.			
:FEED <name>	Select source of readings (SENSe[1], CALCulate[1] or NONE).	CALC		✓
:CONTrol <name>	Select buffer control mode (NEVer, NEXT, ALWays).	NEV		✓
:CONTrol?	Query buffer control mode.			✓
:FEED?	Query source of readings for buffer.			✓
:DATA?	Read all readings in the buffer.			✓
:DATA:SELected? <start>, <count>	Specify readings to be returned; specify starting point (first reading is #0) and number of readings (count).			

*:SYSTem:PRESet and *RST have no effect on commands in this subsystem. The listed defaults are defaults set at the factory.

Table 14-9
Trigger command summary

Command	Description	Default parameter	Ref	SCPI
:INITiate	Subsystem command path:		Sec 7	✓
[:IMMediate]	Initiate one trigger cycle.			✓
:CONTinuous <b>	Enable or disable continuous initiation.	(Note 1)		✓
:CONTinuous?	Query continuous initiation.			✓
:ABORt	Reset trigger system.			✓
:TRIGger[:SEQuence[1]]	Path to program Trigger Layer:			✓
:COUNt <n>	Set measure count (1 to 9999, or INFinity).	(Note 2)		✓
:COUNt?	Query measure count.			✓
:DELay <n>	Set delay (0 to 999999.999 sec).	0		✓
:AUTO <b>	Enable or disable auto delay.	OFF		
:AUTO?	Query state of delay.			
:DELay?	Query delay.			✓
:SOURce <name>	Select control source (IMMediate, TIMer, MANual, BUS, or EXTernal).	IMM		✓
:SOURce?	Query control source.			✓
:TIMer <n>	Set timer interval (0.001 to 999999.999 sec).	0.1		✓
:TIMer?	Request the programmed timer interval.			✓
:SIGNal	Loop around control source.			✓
:SAMPle				
:COUNt <NRf>	Specify sample count (1 to 55000).	1		
:COUNt?	Query sample count.			

Notes:
1. Defaults for continuous initiation:
   :SYSTem:PRESet enables continuous initiation.
   *RST disables continuous initiation.
2. Defaults for count:
   :SYSTem:PRESet sets the count to INF (infinity).
   *RST sets the count to 1.

Table 14-10
UNIT command summary

Command	Description	Default parameter	Ref	SCPI
:UNIT			Sec 3	
:TEMPerature <name>	Select temperature units (C, CEL, F, FAR or K).	C		✓
:TEMPerature?	Query temperature units.			✓
:VOLTage	Path to configure voltage units.			
[:DC] <name> [, <clist>]	Select DCV measurement units (V or DB).	V		
:DB	Path to set DB reference voltage:			
:REFerence <n>	Specify reference in volts (0 to 1000).	1		
:REFerence?	Query reference.			
[:DC]? [<clist>]	Query DCV units.			
:AC <name> [, <clist>]	Select ACV measurement units (V or DB).	V		
:DB	Path to set DB reference voltage.			
:REFerence <n>	Specify reference in volts (le-7 to 1000).	1		
:REFerence?	Query DB reference.			
:AC? [<clist>]	Query ACV units.			

A
Specifications

DC CHARACTERISTICS[1]

CONDITIONS: MED (1 PLC)[2] or 10 PLC or MED (1 PLC) with Digital Filter of 10

FUNCTION	RANGE	RESOLUTION	TEST CURRENT OR BURDEN VOLTAGE	INPUT RESISTANCE OR OPEN CKT. VOLTAGE[3]	ACCURACY: ±(ppm of reading + ppm of range) (ppm = parts per million) (e.g., 10ppm = 0.001%) 24 Hour[4] 23°C±1°	90 Day 23°C±5°	1 Year 23°C±5°	TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C
Voltage[11]	100.0000 mV	0.1 µV		>10 GΩ	15 + 30	25 + 35	30 + 35	(1 + 5)/°C
	1.000000 V	1.0 µV		>10 GΩ	15 + 6	25 + 7	30 + 7	(1 + 1)/°C
	10.00000 V	10 µV		>10 GΩ	10 + 4	20 + 5	30 + 5	(1 + 1)/°C
	100.0000 V	100 µV		10 MΩ ± 1%	15 + 6	35 + 9	45 + 9	(5 + 1)/°C
	1000.000 V[5]	1 mV		10 MΩ ± 1%	20 + 6	35 + 9	50 + 9	(5 + 1)/°C
Resistance[6,8]	100.0000 Ω	100 µΩ	1 mA	6.6 V	20 + 20	80 + 20	100 +20	(8 + 1)/°C
	1.000000 kΩ	1 mΩ	1 mA	6.6 V	20 + 6	80 + 6	100 +6	(8 + 1)/°C
	10.00000 kΩ	10 mΩ	100 µA	6.6 V	20 + 6	80 + 6	100 +6	(8 + 1)/°C
	100.0000 kΩ	100 mΩ	10 µA	12.8 V	20 + 6	80 + 10	100 +10	(8 + 1)/°C
	1.000000 MΩ	1.0 Ω	10 µA	12.8 V	20 + 6	80 + 10	100 +10	(8 + 1)/°C
	10.00000 MΩ[7]	10 Ω	0.7 µA // 10M Ω	7.0 V	150 + 6	200 + 10	400 +10	(30 + 1)/°C
	100.0000 MΩ[7]	100 Ω	0.7 µA // 10M Ω	7.0 V	800 + 30	2000 + 30	2000 +30	(150 + 1)/°C
Continuity (2W)	1.000 kΩ	100 mΩ	1 mA	6.6 V	40 + 100	100 + 100	100 +100	(8 + 1)/°C
Current	20.00000 mA	10 nA	< 0.2 V		60 + 15	300 + 40	500 + 40	(50 +5)/°C
	100.0000 mA	100 nA	< 0.05 V		100 + 150	300 + 400	500 + 400	(50 +50)/°C
	1.000000 A	1.0 µA	< 0.3 V[9]		200 + 15	500 + 40	800 + 40	(50 +5)/°C
	3.000000 A	10 µA	< 1.0 V[9]		1000 + 15	1200 + 40	1200 + 40	(50 +5)/°C
Channel (Ratio)[10]	Ratio Accuracy = Accuracy of selected Channel Range + Accuracy of Paired Channel Range							
Channel (Average)[10]	Average Accuracy = Accuracy of selected Channel Range + Accuracy of Paired Channel Range							

TEMPERATURE[19]

(Displayed in °C, °F, or K. Exclusive of probe errors.)

Thermocouples (Accuracy based on ITS-90.)

Type	Range	Resolution	90 Day/1 Year (23°C ± 5°C) Relative to Simulated Reference Junction	Using CJC from Plug-In Module	Temperature Coefficient 0°–18°C & 28°–50°C
J	–200 to +760 °C	0.001°C	0.2°C	1.0°C	0.03°C/°C
K	–200 to +1372°C	0.001°C	0.2°C	1.0°C	0.03°C/°C
N	–200 to +1300°C	0.001°C	0.2°C	1.0°C	0.03°C/°C
T	–200 to +400°C	0.001°C	0.2°C	1.0°C	0.03°C/°C
E	–200 to +1000°C	0.001°C	0.2°C	1.0°C	0.03°C/°C
R	0 to +1768°C	0.1 °C	0.6°C	1.8°C	0.03°C/°C
S	0 to +1768°C	0.1 °C	0.6°C	1.8°C	0.03°C/°C
B	+350 to +1820°C	0.1 °C	0.6°C	1.8°C	0.03°C/°C

4-Wire RTD:(100Ω platinum [PT100], D100, F100, PT385, PT3916, or user type. Offset compensation On)

–200° to	630°C	0.01 °C	0.06°C	0.003°C/°C

Thermistor: (2.2kΩ, 5kΩ, and 10kΩ.)

-80° to	150°C	0.01 °C	0.08°C	0.002°C/°C

DC SPEED vs. NOISE REJECTION

Rate	Filter	Readings/s[12]	Digits	RMS Noise 10V Range	NMRR	CMRR[14]
10	50	0.1 (0.08)	6.5	< 1.2 µV	110 dB[13]	140 dB
1	Off	15 (12)	6.5	< 4 µV	90 dB[13]	140 dB
0.1	Off	500 (400)	5.5	< 22 µV	—	80 dB
0.01	Off	2000 (1800)	4.5	< 150 µV	—	80 dB

DC OPERATING CHARACTERISTICS[15]

60Hz (50Hz) Operation

FUNCTION	DIGITS	READINGS/s	PLCs
DCV, DCI, Ohms (<10M),	6.5 [12,16]	5 (4)	10
Thermocouple,	6.5[16]	30 (24)	1
Thermistor	6.5 [12,16]	50 (40)	1
	5.5 [12,16]	100 (80)	0.1
	5.5 [16, 17]	250 (200)	0.1
	5.5 [17]	480 (400)	0.1
	4.5 [17]	2000 (1800)	0.01
4W Ohms (<10M)	6.5[16]	1.4 (1.1)	10
	6.5[16]	15 (1)	1
	5.5 [17]	33 (25)	0.1
RTD	6.5[16]	0.9 (0.7)	10
	6.5[16]	8 (6.4)	1
	5.5 [16, 17]	18 (14.4)	0.1
Channel (Ratio),	6.5[16]	2.5 (2)	10
Channel (AVG)	6.5[16]	15 (12)	1
	5.5 [17]	25 (20)	0.1

DC SYSTEM SPEEDS[15,18]

RANGE CHANGES[16]: 50/s (42/s).
FUNCTION CHANGES[16]: 50/s (42/s).
AUTORANGE TIME[16]: < 30ms.
ASCII READINGS TO RS-232 (19.2k BAUD): 55/s.
MAX. INTERNAL TRIGGER RATE: 2000/s.
MAX. EXTERNAL TRIGGER RATE: 375/s.

DC MEASUREMENT CHARACTERISTICS

DC Volts

A-D LINEARITY: 2.0 ppm of reading + 1.0 ppm of range.
INPUT IMPEDANCE:
100mV–10V Ranges: Selectable >10GΩ// with <400pF or 10MΩ ±1%.
100V, 1000V Ranges: 10MΩ ±1%.
INPUT BIAS CURRENT: <75pA at 23°C.
COMMON MODE CURRENT: <500nApp at 50Hz or 60 Hz.
AUTOZERO ERROR: Add ±(2ppm of range error + 5μV) for < 10 minutes and ±1°C.
INPUT PROTECTION: 1000V, all ranges. 300V with plug in modules.

Resistance

MAX 4WΩ LEAD RESISTANCE: 10% of range per lead for 100Ω and 1kΩ ranges; 1kΩ per lead for all other ranges.
OFFSET COMPENSATION: Selectable on 4WΩ 100Ω, 1kΩ, and 10kΩ ranges.
CONTINUITY THRESHOLD: Adjustable 1 to 1000 Ω
INPUT PROTECTION: 1000V, all Source Inputs, 350V Sense Inputs. 300V with plug-in modules.

DC Current

SHUNT RESISTORS: 100mA–3A, 0.1Ω. 20mA, 5Ω.
INPUT PROTECTION: 3A, 250V fuse.

Thermocouples

CONVERSION: ITS-90.

REFERENCE JUNCTION: Internal, External, or Simulated (Fixed).

OPEN CIRCUIT CHECK: Selectable per channel. Open >12kΩ.

EARTH ISOLATION: 500V peak, >10GΩ and <150pF any terminal to chassis.

DC Notes

1. 20% overrange except on 1000V and 3A.
2. Add the following to "ppm of range" uncertainty; 100mV 15ppm, 1V and 100V 2ppm, 100Ω 30ppm, <1MΩ 2ppm, 10mA and 1A 10ppm, 100mA 40ppm.
3. ±2% (measured with 10MΩ input resistance DMM, >10GΩ DMM on 10MΩ and 100MΩ ranges).
4. Relative to calibration accuracy.
5. For signal levels >500V, add 0.02ppm/V uncertainty for portion exceeding 500V.
6. Specifications are for 4-wire Ω, 100Ω with offset compensation on. With offset compensation on, OPEN CKT. VOLTAGE is 12.8V. For 2-wire Ω add 1Ω additional uncertainty.
7. Must have 10% matching of lead resistance in Input HI and LO.
8. Add the following to "ppm of reading" uncertainty when using plug in modules:

	10 kΩ	100 kΩ	1 MΩ	10 MΩ	100 MΩ
All Modules:				220 ppm	2200 ppm
7703 Module: for <40% R.H. operating environment	10 ppm	100 ppm	1000 ppm	1%	10%
7706 Module:	5 ppm	50 ppm	500 ppm	5000 ppm	5%

9. Add 1V when used with plug in modules.
10. For RATIO, DCV only. For AVERAGE, DCV and Thermocouples only. Available with plug in modules only.
11. Add 6μV to "of range" uncertainty when using Model 7703 and 3μV for Model 7706.
12. Auto zero off.
13. For LSYNC On, line frequency ±0.1 %. For LSYNC Off, use 60dB for ≥ 1PLC.
14. For 1kΩ unbalance in LO lead. AC CMRR is 70dB.
15. Speeds are for 60Hz (50Hz) operation using factory defaults operating conditions (*RST). Autorange off, Display off, Limits off, Trigger delay = 0.
16. Speeds include measurements and binary data transfer out the GPIB.
17. Sample count = 1024, auto zero off.
18. Auto zero off, NPLC = 0.01.
19. Add additional uncertainty of ±0.25% of reading for type J, K, N, T, and E for measurement temperatures <0°C. Add ±0.5°C uncertainty for types R and S <+400°C, and for type B <+1100°C. For Model 7706, add additional uncertainty of ±0.8% of reading for type J, K, N, T, and E for measurement temperatures <0°C. Add ±1°C uncertainty for type R and S <+400°C and type B <+1100°C. Guaranteed by design for types B, E, N, R, and S.
20. For lead resistance >0Ω, add the following uncertainty/Ω for measurement temperatures of:

	70°–100°C	100°–150°C
2.2 kΩ (44004)	0.22°C	1.11°C
5.0 kΩ (44007)	0.10°C	0.46°C
10 kΩ (44006)	0.04°C	0.19°C

AC SPECIFICATIONS[1]

Function	Range	Resolution	Calibration Cycle	Accuracy: ±(% of reading + % of range), 23°C ± 5°C 3 Hz–10 Hz	10 Hz–20 kHz	20 kHz–50 kHz	50 kHz–100 kHz	100 kHz–300 kHz
Voltage[2]	100.0000 mV	0.1 µV	90 Days	0.35 + 0.03	0.05 + 0.03	0.11 + 0.05	0.6 + 0.08	4.0 + 0.5
	1.000000 V	1.0 µV						
	10.00000 V	10 µV	1 Year	0.35 + 0.03	0.06 + 0.03	0.12 + 0.05	0.6 + 0.08	4.0 + 0.5
	100.0000 V	100 µV						
	750.000 V	1.0 µV	(Temp. Coeff.)/°C[3]	0.035 + .003	0.005 + .003	0.006 + .005	0.01 + .006	0.03 + .01

				3 Hz–10 Hz	10 Hz–5 kHz
Current[2]	1.000000 A	1.0 µA	90 Day/1 Yr.	0.30 + 0.04	0.10 + 0.04
	3.00000 A	10 µA		0.35 + 0.06	0.15 + 0.06
			(Temp. Coeff.)/°C[3]	0.035 + 0.006	0.015 + 0.006

				(3 Hz–500 kHz) (333 ms–2 µs)
Frequency[4] and Period	100 mV to 750 V	0.333 ppm 3.33 ppm 33.3 ppm	90 Day/ 1 Yr.	100 ppm + 0.333 ppm (SLOW, 1s gate) 100 ppm + 3.33 ppm (MED, 100ms gate) 100 ppm + 33.3 ppm (FAST, 10ms gate)

Additional Uncertainty ±(% of reading)

Low Frequency Uncertainty	MED	FAST
20 Hz - 30 Hz	0.3	—
30 Hz - 50 Hz	0	—
50 Hz - 100 Hz	0	1.0
100 Hz - 200 Hz	0	0.18
200 Hz - 300 Hz	0	0.10
>300 Hz	0	0

CREST FACTOR:[5]	1 -2	2 - 3	3 - 4	4 - 5
Additional Uncertainty:	0.05	0.15	0.30	0.40

AC MEASUREMENT CHARACTERISTICS

AC Volts

MEASUREMENT METHOD: AC-coupled, True RMS.

INPUT IMPEDANCE: 1MΩ ±2% // by <100pF.

INPUT PROTECTION: 1000Vp or 400VDC. 300Vrms with plug in modules.

AC Current

MEASUREMENT METHOD: AC-coupled, True RMS.

SHUNT RESISTANCE: 0.1Ω.

BURDEN VOLTAGE: 1A <0.3Vrms, 3A <1Vrms. Add 1Vrms when used with plug in modules.

INPUT PROTECTION: 3A, 250V fuse.

Frequency and Period

MEASUREMENT METHOD: Reciprocal Counting technique.

GATE TIME: SLOW 1s, MED 100ms, and FAST 10ms.

AC General

AC CMRR[6]: 70dB.

MAXIMUM CREST FACTOR: 5 at full-scale.

VOLT HERTZ PRODUCT: <= 8×10^7.

AC OPERATING CHARACTERISTICS[7]

60Hz (50Hz) Operation

Function	Digits	Readings/s	Rate	Bandwidth
ACV, ACI	6.5[8]	2s/Reading	SLOW	3 Hz–300 kHz
	6.5[8]	1.4 (1.1)	MED	30 Hz–300 kHz
	6.5[9]	4.8 (4)	MED	30 Hz–300 kHz
	6.5[9]	35 (28)	FAST	300 Hz–300 kHz
Frequency, Period	6.5	1 (1)	SLOW	3 Hz–300 kHz
	5.5	9 (9)	MED	30 Hz–300 kHz
	4.5	35 (35)	FAST	300 Hz–300 kHz
	4.5[10]	65 (65)	FAST	300 Hz–300 kHz

AC System Speeds[7, 11]

RANGE CHANGES[12]: 4/s (3/s).

FUNCTION CHANGES[12]: 4/s (3/s).

AUTORANGE TIME: < 3s.

ASCII READINGS TO RS-232 (19.2k baud): 50/s.

MAX. INTERNAL TRIGGER RATE: 300/s.

MAX. EXTERNAL TRIGGER RATE: 250/s.

AC Notes

1. 20 % overrange except on 750V and 3A.
2. Specification are for SLOW mode and sine wave inputs >5% of range. SLOW and MED are multi-sample A/D conversions. FAST is DETector:BANDwidth 300 with nPLC = 1.0.
3. Applies to 0°–18°C and 28°–50°C.
4. For square wave inputs >10% of ACV range, except 100mV range. 100mV range frequency must be >10Hz if input is <20mV.
5. Applies to non-sine waves >5Hz.
6. For 1kΩ unbalance in LO lead.
7. Speeds are for 60Hz (50Hz) operation using factory defaults operating conditions (*RST). Autorange off, Display off, Limits off, Trigger delay=0. Includes measurement and binary data transfer out GPIB.
8. 0.01% of step settling error. Trigger delay = 400ms.
9. Trigger delay = 0.
10. Sample count = 1024.
11. DETector:BANDwidth 300 with nPLC = 0.01.
12. Maximum useful limit with trigger delay = 175ms.

Internal Scanner Speeds:

Into and Out of Memory to GPIB[1]

7703 Scanning DCV	185/s
7703 Scanning DCV with Limits or Time Stamp On	150/s
7703 Scanning ACV[2, 3]	155/s
7703 Scanning DCV alternating 2W	60/s
7702 Scanning DCV	60/s
7700 Scanning Temperature (T/C)	55/s
7706 Scanning DCV	50/s

Internal Scanner Speed Notes:

1. Speeds are 60Hz or 50Hz operation using factory default conditions (*RST). NPLC = 0.01. Auto Zero off, Auto Range off, and Display off. Sample count =1024. Includes measurement and binary data transfer out GPIB.
2. Detector Bandwidth = 300.
3. For Auto Delay On = 1.8/s.

GENERAL SPECIFICATIONS:

POWER SUPPLY: 100V / 120V / 220V / 240V ±10%.

LINE FREQUENCY: 45Hz to 66Hz and 360Hz to 440Hz, automatically sensed at power-up.

POWER CONSUMPTION: 28VA.

OPERATING ENVIRONMENT: Specified for 0°C to 50°C. Specified to 80% RH at 35°C.

STORAGE ENVIRONMENT: –40°C to 70°C.

BATTERY: Lithium battery-backed memory, 3 years @ 23°C.

WARRANTY: 3 years.

EMC: Conforms to European Union Directive 89/336/EEC EN61326-1.

SAFETY: Conforms to European Union Directive 73/23/EEC EN61010-1, CAT I.

VIBRATION: MIL-PRF-28800F Class 3, Random.

WARM-UP: 2 hours to rated accuracy.

DIMENSIONS:

Rack Mounting: 89mm high × 213mm wide × 370mm deep (3.5 in × 8.375 in × 14.563 in).

Bench Configuration (with handle and feet): 104mm high × 238mm wide × 370mm deep (4.125 in × 9.375 in × 14.563 in).

SHIPPING WEIGHT: 6.5kg (14 lbs.).

DIGITAL I/O: 2 inputs, 1 for triggering and 1 for hardware interlock. 5 outputs, 4 for Reading Limits and 1 for Master Limit. Outputs are TTL compatible or can sink 250mA, diode clamped to 33V.

TRIGGERING AND MEMORY:

Window Filter Sensitivity: 0.01%, 0.1 %, 1%, 10%, or Full-scale of range (none).

Reading Hold Sensitivity: 0.01%, 0.1 %, 1%, or 10% of reading.

Trigger Delay: 0 to 99 hrs (1ms step size).

External Trigger Delay: <2ms.

External Trigger Jitter: <1ms.

Memory Size: 55,000 readings.

MATH FUNCTIONS: Rel, Min/Max/Average/Std Dev/Peak-to-Peak (of stored reading), Limit Test, %, and mX + b with user defined units displayed.

REMOTE INTERFACE:

Keithley XLinx Up & Running starter software
GPIB (IEEE-488.2) and RS-232C.
SCPI (Standard Commands for Programmable Instruments)
LabVIEW Drivers
TestPoint Drivers

ACCESSORIES SUPPLIED: Model 1751 Safety Test Leads, User Manual, Service Manual.

7700 20-Channel Differential Multiplexer w/Automatic CJC

GENERAL

20 CHANNELS: 20 channels of 2-pole relay input. All channels configurable to 4-pole.

2 CHANNELS: 2 channels of current only input.

RELAY TYPE: Latching electromechanical.

ACTUATION TIME: <3ms.

CAPABILITIES

CHANNELS 1-20: Multiplex one of 20 2-pole or one of 10 4-pole signals into DMM.

CHANNELS 21-22: Multiplex one of 2 2-pole current signals into DMM.

INPUTS

MAXIMUM SIGNAL LEVEL:

Channels (1-20): 300V DC or rms, 1A switched, 60W, 125VA maximum.

Channels (21-22): 60V DC or 30V rms, 3A switched, 60W, 125VA maximum.

CONTACT LIFE (typ): $>10^5$ operations at max signal level.
$>10^8$ operations cold switching.

CONTACT RESISTANCE: <1Ω at end of contact life.

CONTACT POTENTIAL: <±500nV typical per contact, 1µV max.
<±500nV typical per contact pair, 1µV max.

OFFSET CURRENT: <100pA.

CONNECTOR TYPE: Screw terminal, #20 AWG wire size.

ISOLATION BETWEEN ANY TWO TERMINALS: $>10^{10}\Omega$, <100pF.

ISOLATION BETWEEN ANY TERMINAL AND EARTH: $>10^9\Omega$, <200pF.

CROSS TALK (10MHz, 50Ω Load): <–40dB.

INSERTION LOSS (50Ω Source, 50Ω Load): <0.1dB below 1MHz.
<3dB below 2MHz.

COMMON MODE VOLTAGE: 300V between any terminal and chassis.

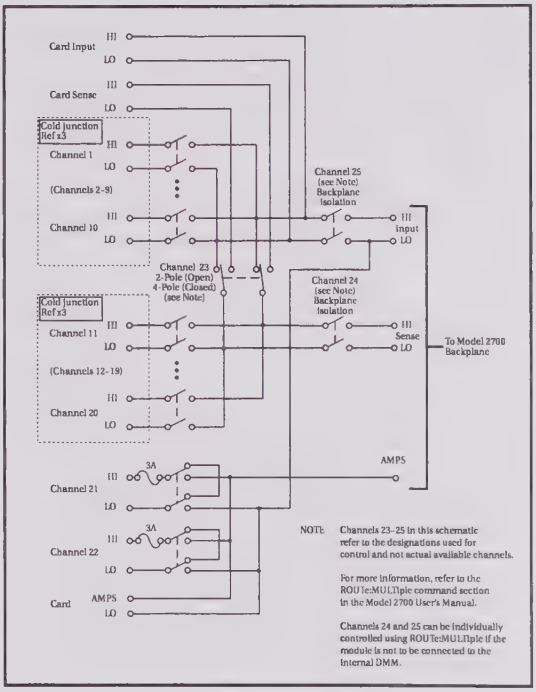
T/C COLD JUNCTION: 1.0°C (18°–28°C Mainframe Temp)
1.5°C (0°–18°C & 28°–50°C Mainframe Temp).

ENVIRONMENTAL:

OPERATING ENVIRONMENT: Specified for 0°C to 50°C.
Specified to 80% R.H. at 35°C.

STORAGE ENVIRONMENT: –25°C to 65°C.

WEIGHT: 0.45kg (1 lb).



7702 40-Channel Differential Multiplexer

GENERAL

40 CHANNELS: 40 channels of 2-pole relay input.
All channels configurable to 4-pole.

2 CHANNELS: 2 channels of current only input.

RELAY TYPE: Latching electromechanical.

ACTUATION TIME: <3ms.

CAPABILITIES

CHANNELS 1-40: Multiplex one of 40 2-pole or one of 20 4-pole signals into DMM.

CHANNELS 41-42: Multiplex one of 2 2-pole current signals into DMM.

INPUTS

MAXIMUM SIGNAL LEVEL:

Channels (1-40): 300V DC or rms, 1A switched, 60W, 125VA maximum.

Channels (41-42): 60V DC or 30V rms, 3A switched, 60W, 125VA maximum.

CONTACT LIFE (typ): $>10^5$ operations at max signal level.
$>10^8$ operations cold switching.

CONTACT RESISTANCE: <1Ω at end of contact life.

CONTACT POTENTIAL: <±500nV typical per contact, 1µV max.
<±500nV typical per contact pair, 1µV max.

OFFSET CURRENT: <100pA.

CONNECTOR TYPE: Screw terminal, #20 AWG wire size.

ISOLATION BETWEEN ANY TWO TERMINALS: $>10^{10}\Omega$, <100pF.

ISOLATION BETWEEN ANY TERMINAL AND EARTH: $>10^9\Omega$, <200pF.

CROSS TALK (10MHz, 50Ω Load): <–40dB.

INSERTION LOSS (50Ω Source, 50Ω Load): <0.1dB below 1MHz.
<3dB below 2MHz.

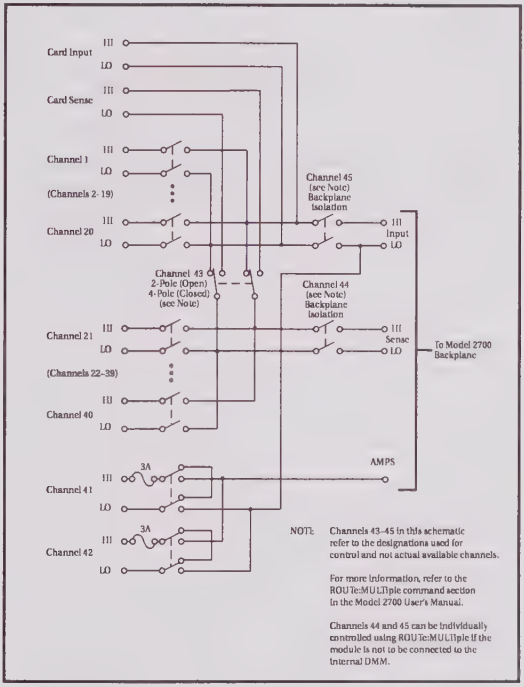
COMMON MODE VOLTAGE: 300V between any terminal and chassis.

ENVIRONMENTAL

OPERATING ENVIRONMENT: Specified for 0°C to 50°C.
Specified to 80% R.H. at 35°C.

STORAGE ENVIRONMENT: –25°C to 65°C.

WEIGHT: 0.5kg (1.1 lb).



7703 32-Channel High Speed Differential Multiplexer

GENERAL

32 CHANNELS: 32 channels of 2-pole relay input.
All channels configurable to 4-pole.

RELAY TYPE: Reed.

ACTUATION TIME: <1ms.

CAPABILITIES

CHANNELS 1-32: Multiplex one of 32 2-pole or one of 16 4-pole signals into DMM.

INPUTS

MAXIMUM SIGNAL LEVEL:

Channels (1-32): 300V DC or rms, 0.5A switched, 10W maximum.

Contact Life (typ): $>5\times10^4$ operations at max signal level.
$>10^8$ operations cold switching.

CONTACT RESISTANCE: <1Ω at end of contact life.

CONTACT POTENTIAL: <±3μV typical per contact, 6μV max.
<±3μV typical per contact pair, 6μV max.

OFFSET CURRENT: <100pA.

CONNECTOR TYPE: 50 pin D-sub × 2.

RELAY DRIVE CURRENT: 20mA per channel.

ISOLATION BETWEEN ANY TWO TERMINALS: $>10^9\Omega$, <200pF.

ISOLATION BETWEEN ANY TERMINAL AND EARTH: $>10^9\Omega$, <400pF.

CROSS TALK (1 MHz, 50Ω Load): <–40dB.

INSERTION LOSS (50Ω Source, 50Ω Load): <0.35dB below 1MHz.
<3dB below 2MHz.

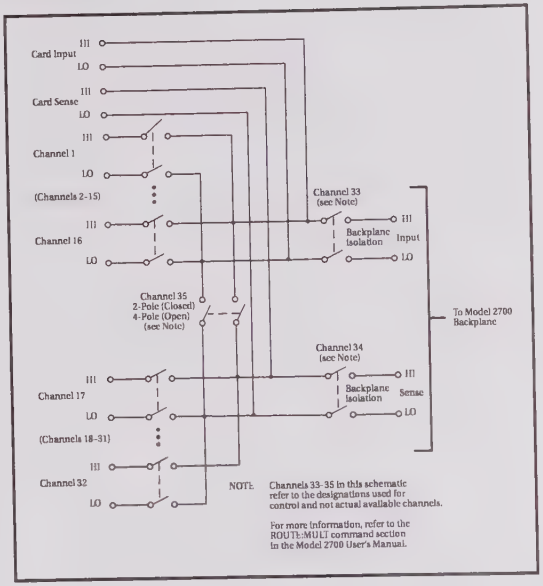
COMMON MODE VOLTAGE: 300V between any terminal and chassis.

ENVIRONMENTAL

OPERATING ENVIRONMENT: Specified for 0°C to 50°C.
Specified to 40% R.H. at 35°C.

STORAGE ENVIRONMENT: –25°C to 65°C.

WEIGHT: 0.8kg (1.75 lbs).



7705 40-Channel Control Module

GENERAL

RELAY SWITCH CONFIGURATION: 40 independent channels of 1-pole switching. Isolated from internal DMM.

CONTACT CONFIGURATION: 1 pole Form A.

RELAY TYPE: Latching electromechanical.

CONNECTOR TYPE: Two 50-pin female D-sub connectors.

INPUTS

MAXIMUM SIGNAL LEVEL: 300VDC or rms, 2A switched, 60W (DC, resistive), 125VA (AC, resistive).

CONTACT LIFE: **Cold Switching:** 10^8 closures.
At Maximum Signal Levels: 10^5 closures.

CHANNEL RESISTANCE (per conductor): <1Ω.

CONTACT POTENTIAL: ≤4μV per contact.

OFFSET CURRENT: <100pA.

ACTUATION TIME: 3ms.

ISOLATION: **Channel to Channel:** $>10^9\Omega$, <50pF.
Common Mode: $>10^9\Omega$, <100pF.

CROSSTALK (1MHz, 50Ω load): <–35dB.

INSERTION LOSS (50Ω source, 50Ω load): <0.3dB below 1MHz, <3dB below 10MHz.

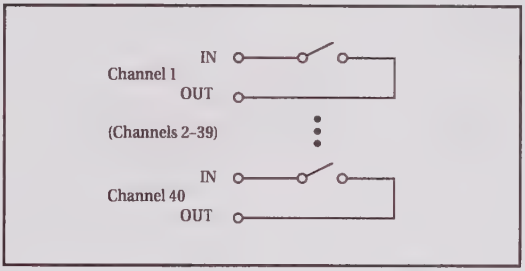
COMMON MODE VOLTAGE: 300V between any terminal and chassis.

ENVIRONMENTAL

OPERATING ENVIRONMENT: Specified for 0°C to 50°C.
Specified to 80% R.H. at 35°C.

STORAGE ENVIRONMENT: –25°C to 65°C.

WEIGHT: 0.45kg (1 lb).



7706 All-in-One I/O Module

GENERAL

20 CHANNELS: 20 channels of 2-pole relay input.
All channels configurable to 4-pole.

RELAY TYPE: Latching electromechanical.

ACTUATION TIME: <3ms.

CAPABILITIES

CHANNELS 1–20: Multiplex one of 20 2-pole or one of 10 4-pole signals into DMM.

Channels 21–25 are referenced to chassis ground.

CHANNELS 21–22: 16 Digital Outputs.

CHANNELS 23–24: Analog Voltage Output (2).

CHANNELS 25: Totalize Input.

INPUTS (Channels 1–20)

MAXIMUM SIGNAL LEVEL (Channels 1–20): 300V DC or rms, 1A switched, 60W, 125VA maximum.

SAFETY CATEGORY: CAT I.

CONTACT LIFE (typ.): $>10^5$ operations at max. signal level: $>10^8$ operations cold switching.

CONTACT RESISTANCE: <1Ω at end of contact life.

CONTACT POTENTIAL: <±2µV typical per contact pair, 3µV max.

OFFSET CURRENT: <100pA.

CONNECTOR TYPE: Screw terminal, #22 AWG wire size.

ISOLATION BETWEEN ANY TWO TERMINALS: $>10^9$Ω, <100pF with isolation channels 27 and 28 open.

ISOLATION BETWEEN ANY TERMINAL AND EARTH: $>10^9$Ω, <200pF.

CROSS TALK (10MHz, 50Ω Load): <–35dB.

INSERTION LOSS (50Ω Source, 50Ω Load): <0.1dB below 1MHz.
<3dB below 2MHz.

COMMON MODE VOLTAGE: 300V between any terminal and chassis.

DIGITAL OUTPUT (Channels 21 and 22)

V_{OUT}(L): <0.8V @ Iout = 400mA.

V_{OUT}(H): >2.4V @ Iout = 1mA.

V_{OUT}(H)MAX.: <42V with external open drain pull-up.

WRITE SPEED: 50/s.

ANALOG VOLTAGE OUTPUT (Channels 23 and 24)

DAC 1, 2: ±12V, non-isolated.

RESOLUTION: 1mV.

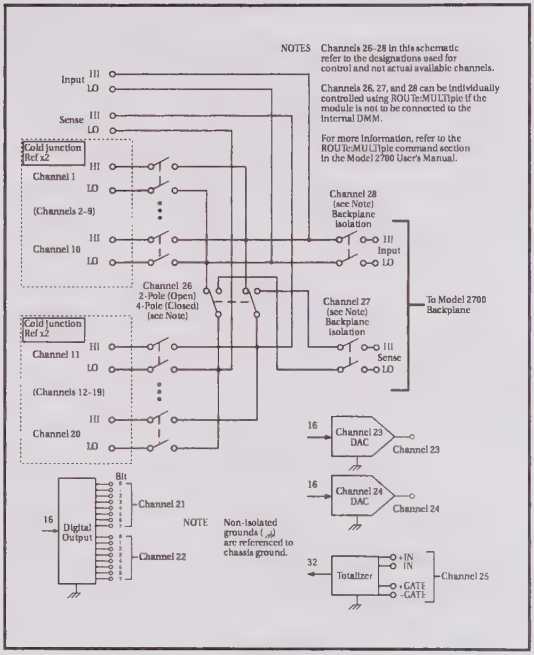
I_{OUT}: 5mA max.

SETTLING TIME: 1ms to 0.01% of output.

ACCURACY ±(% of output + mV):
Measured with ≥10MΩ input resistance DMM.
1 year ±5°C: 0.15% + 19mV;
90 day ±5°C: 0.1% + 19mV;
24 hour ±1°C: 0.04% + 19mV.

TEMPERATURE COEFFICIENT: ±(0.015% + 1mV)/°C.

WRITE SPEED: 50/s.


NOTES
Channels 26–28 in this schematic refer to the designations used for control and not actual available channels.
Channels 26, 27, and 28 can be individually controlled using ROUTe:MULTiple if the module is not to be connected to the internal DMM.
For more information, refer to the ROUTe:MULTiple command section in the Model 2700 User's Manual.
Input
Sense
Cold Junction Ref x2
Channel 1
(Channels 2–9)
Channel 10
Channel 28 (see Note) Backplane Isolation
Channel 26 2-Pole (Open) 4-Pole (Closed) (see Note)
Channel 27 (see Note) Backplane Isolation
To Model 2700 Backplane
Channel 11
(Channels 12–19)
Channel 20
Channel 23 DAC
Channel 24 DAC
Bit
Digital Output
Channel 21
Channel 22
NOTE
Non-isolated grounds (⏚) are referenced to chassis ground.
Totalizer
+IN
-IN
+GATE
-GATE
Channel 25

TOTALIZE INPUT (Channel 25)

MAXIMUM COUNT: 2^{32}–1.

TOTALIZE INPUT: 100kHz (max), rising or falling edge, programmable.

SIGNAL LEVEL: 1Vp-p (min), 42Vpk (max).

THRESHOLD: 0V or TTL, jumper selectable.

DATE INPUT: TTL-Hi, TTL-Lo, or none.

COUNT RESET: manual or Read+Reset.

READ SPEED: 50/s.

ENVIRONMENTAL

Specified for Model 2700, firmware revision A02 or later.

OPERATING ENVIRONMENT: Specified for 0°C to 50°C.
Specified to 80% R.H. at 35°C.

STORAGE ENVIRONMENT: –25°C to 65°C.

WEIGHT: 0.5kg (1.1 lbs).

ALL SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE

B
Models 7700, 7702, and 7703

Introduction

This section contains information specific to modules that directly connect to the Model 2700's DMM. The information is organized as follows:

- Model 7700
- Model 7702
- Model 7703

For Models 7705 and 7706, refer to the Appendices C and D respectively.

If you have any questions after reviewing this information, please contact your local Keithley representative or call one of our Applications Engineers at 1-800-348-3735 (U.S. and Canada only). Worldwide phone numbers are listed at the front of this manual.

Model 7700

The Model 7700 is a 20-channel differential multiplexer card with the following features:

- 2-wire or 4-wire Ω measurement (automatically pairs switches for four wire measurements — $n + 10$)
- Temperature applications (RTD, thermistor, thermocouple)
- Built-in cold junction reference
- Screw terminal connections
- Two protected channels for current measurements (external shunts not required)
- Designed specifically for use with Keithley's Model 2700 Multimeter/Data Acquisition System.

Card configuration — schematic

Figure B-1 shows a simplified schematic diagram of the Model 7700 module. As shown, the Model 7700 has channels that are grouped into two banks of ten channels (twenty channels total). Backplane isolation is provided for each bank. Each bank also includes separate cold junction reference points. The first bank contains channels 1 through 10 while the second bank contains channels 11 through 20. Each channel of the 20-channel multiplexer card is wired with separate inputs for HI/LO providing fully isolated inputs. The Model 7700 also provides two channels of current input, Channels 21 and 22.

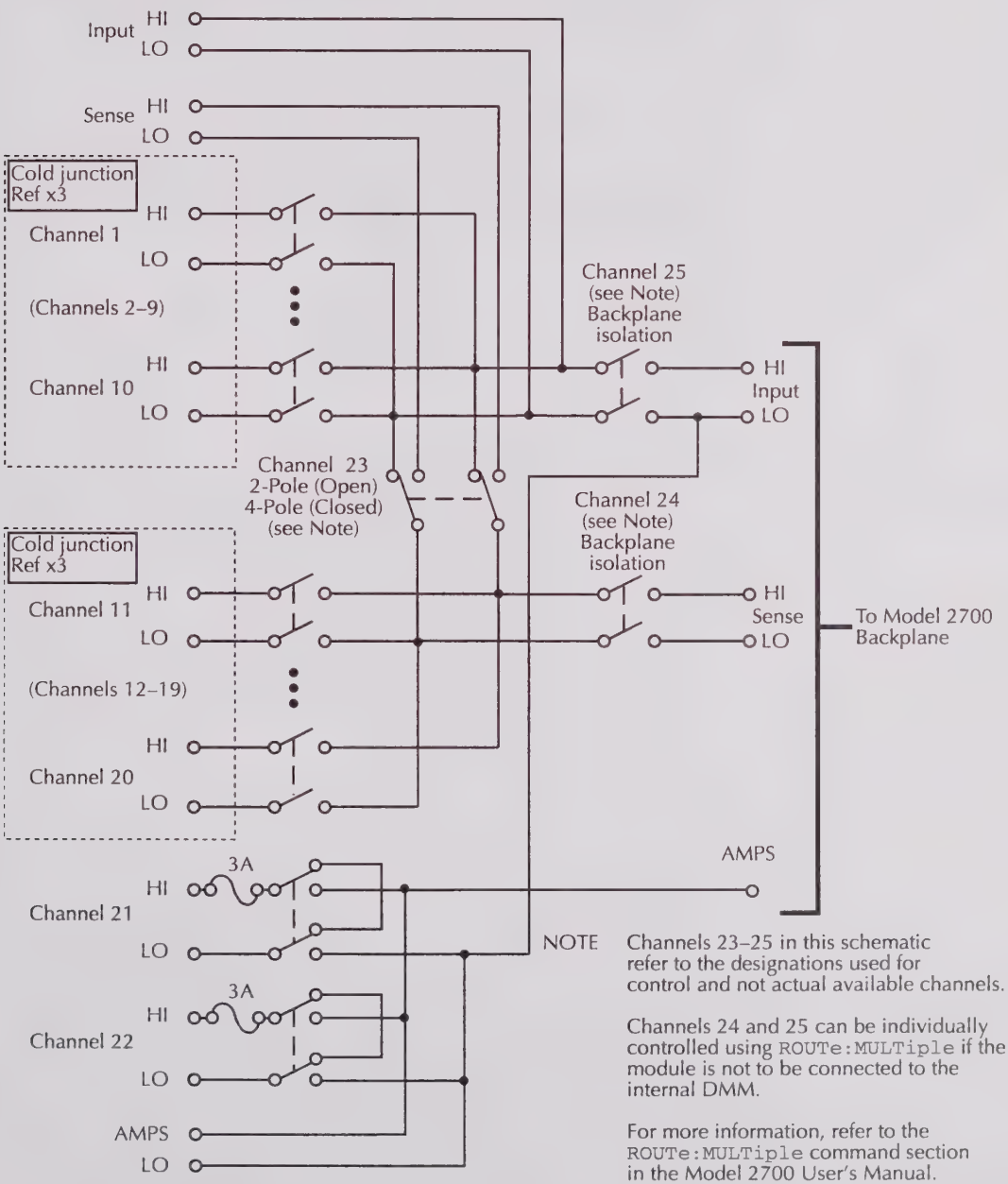
Although the Model 7700 relays are the latching type (relays hold their state even after power has been removed), all relay states are set to open a few seconds after either a power cycle or a *RST command is issued.

Connections to DMM functions are provided through the card backplane connector.

- Current provided through two protected channels (Channels 21 and 22).
- INPUT connections
- SENSE (Ω4-wire) connections

AMP and LO common connections to the DMM are also provided.

Figure B-1
Simplified schematic for Model 7700



Channel 23 (2W/4W Configuration), Channel 24 (Sense Isolation), and Channel 25 (Input Isolation) are normally automatically configured by the 2700. However, by using the `:ROUT:MULT:` commands (refer to Section 2), they can be manually configured.

NOTES *Connect 4-wire sense leads using channels 11–20.*

To disconnect channels 11–20 from channels 1–10, send:
`:ROUT:MULT:CLOS (@123)` *(note opposite logic)*

When automatically configured for 4-wire measurements (including 4-wire Ω, RTD temperature, Ratio, and Channel average) the channels are paired as follows:

- CH1 and CH11
- CH2 and CH12
- CH3 and CH13
- CH4 and CH14
- CH5 and CH15
- CH6 and CH16
- CH7 and CH17
- CH8 and CH18
- CH9 and CH19
- CH10 and CH20

Card configuration — connections

WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

Figure B-2 shows how to access the screw terminals on the Model 7700. Channel designations for the screw terminals are contained in Figure B-3.

WARNING **Do not exceed the maximum specifications for the Model 7700 module. Refer to Appendix A for specifications.**

Figure B-2
Screw terminal access

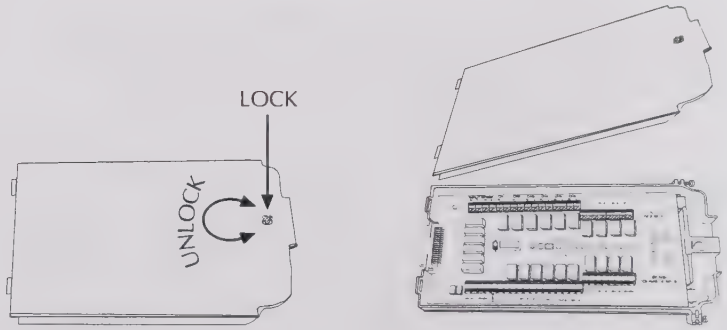
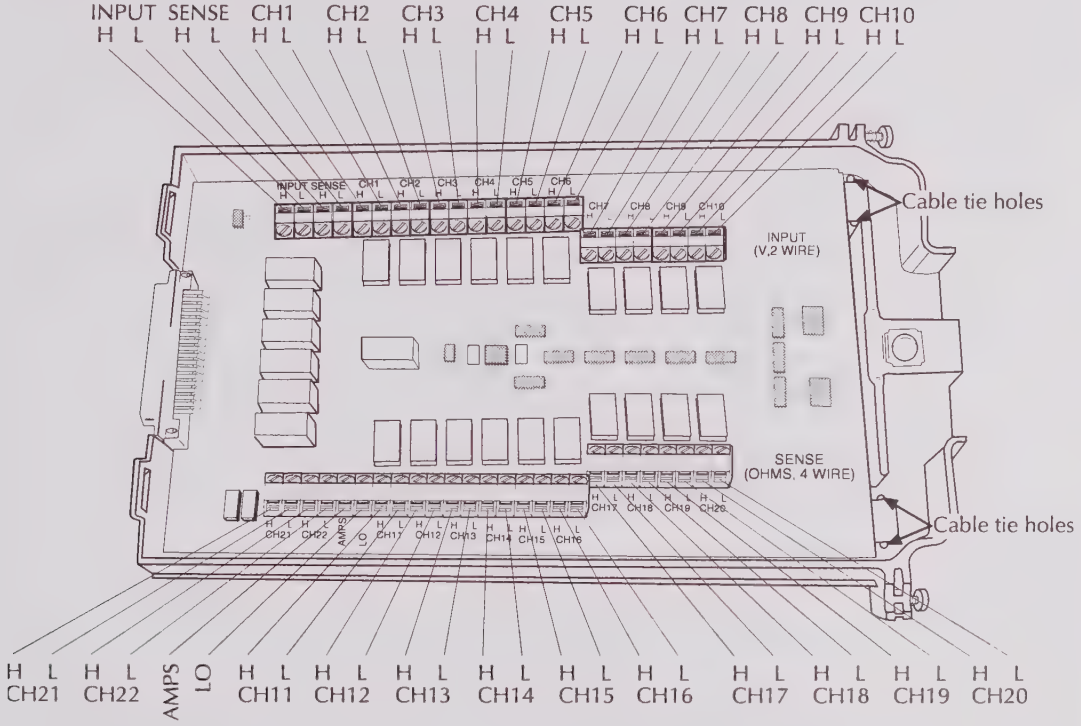


Figure B-3
Model 7700 Screw terminal channel designations


INPUT SENSE CH1 CH2 CH3 CH4 CH5 CH6 CH7 CH8 CH9 CH10
H L H L H L H L H L H L H L H L H L H L
Cable tie holes
INPUT
(V,2 WIRE)
SENSE
(OHMS, 4 WIRE)
Cable tie holes
H L H L AMPS LO H L H L H L H L H L H L H L H L H L H L
CH21 CH22 CH11 CH12 CH13 CH14 CH15 CH16 CH17 CH18 CH19 CH20

Wiring procedure

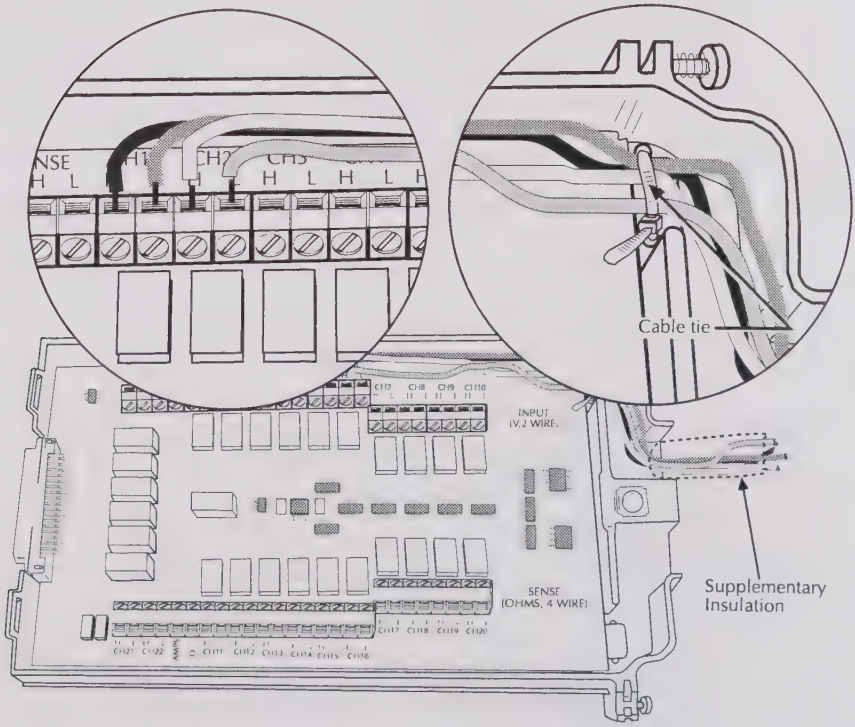
WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

Use the following procedure to wire the Model 7700 module. Make all connections using correct wire size (up to 20 AWG). Also, make sure to add supplementary insulation around the harness for voltages above 42V peak (see Figure B-4).

WARNING **All wiring and supplementary insulation must be rated for the maximum voltage in the system. For example, if 1000V is applied to the front terminals of the Model 2700, the plug-in module wiring must be rated for 1000V.**

1. Make sure all power is discharged from the Model 7700 module.
2. Access the screw terminals (see Figure B-2).
3. Using a small flat-blade screwdriver, loosen terminal screws and install wires as desired. (Figure Figure B-4 shows connections to channels 1 and 2.)
4. Route wire along wire-path and secure with cable tie as shown.
5. Fill-in a copy of the connection log (Table B-1) and affix it to the module cover.
6. Close and lock cover.

Figure B-4
Wire dressing



Typical connections

The following examples show typical wiring connections for the following types of measurements:

- Thermocouple connections, see Figure B-5
- Ω2-Wire and Thermistor connections, see Figure B-6
- Ω4-Wire and RTD connections, see Figure B-7
- Current (AC or DC), see Figure B-8
- Voltage (AC or DC), see Figure B-9

Figure B-5
Thermocouple connections

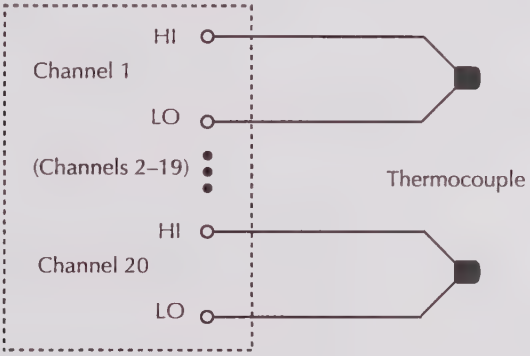


Figure B-6
Ω2-Wire and Thermistor connections

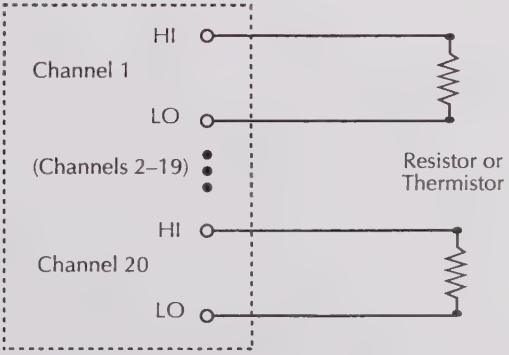


Figure B-7
Ω4-Wire and RTD connections

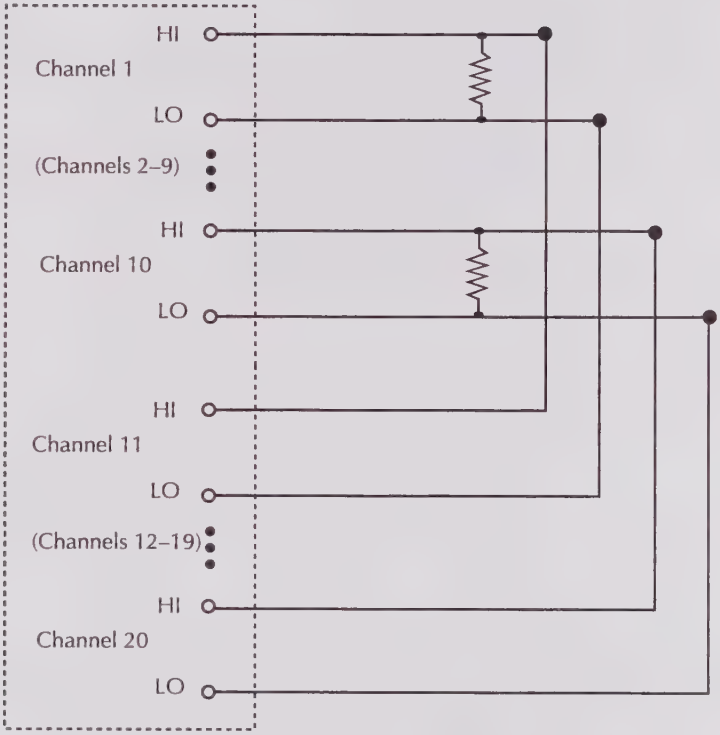


Figure B-8
Current connections (AC or DC)

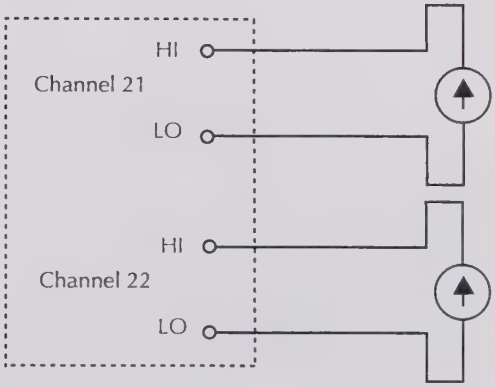
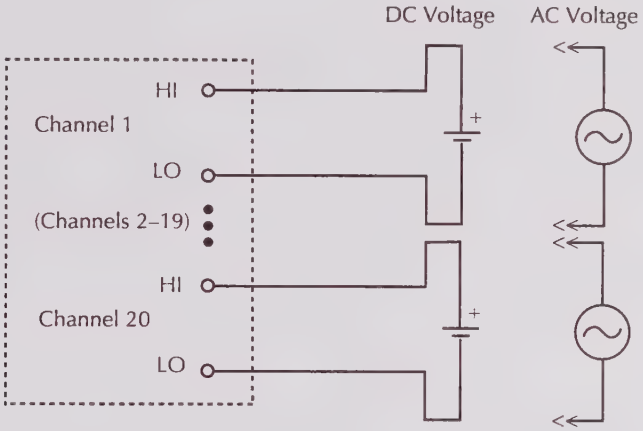


Figure B-9
Voltage connections (DC or AC)



Specifications

Full Model 7700 specifications are included in Appendix A of this manual.

Connection log

Make a copy of Table B-1 and affix it to the cover of the Model 7700. Use this to record connection information and channel descriptions as needed.

Table B-1
Connection log Model 7700

Channel		Color	Description
AMPS COM	H		
	L		
INPUT	H		
	L		
SENSE	H		
	L		
CH1	H		
	L		
CH2	H		
	L		
CH3	H		
	L		
CH4	H		
	L		
CH5	H		
	L		
CH6	H		
	L		
CH7	H		
	L		
CH8	H		
	L		
CH9	H		
	L		
CH10	H		
	L		
CH11	H		
	L		
CH12	H		
	L		
CH13	H		
	L		
CH14	H		
	L		
CH15	H		
	L		
CH16	H		
	L		
CH17	H		
	L		
CH18	H		
	L		
CH19	H		
	L		
CH20	H		
	L		
AMPS 21	H		
	L		
AMPS 22	H		
	L		

Model 7702

The Model 7702 is a 40-channel differential multiplexer card with the following features:

- 2-wire or 4-wire Ω measurement (automatically pairs switches for four wire measurements — $n + 20$)
- Temperature applications (RTD, thermistor, thermocouple)
- Screw terminal connections
- Two protected channels for current measurements (external shunts not required)
- Designed specifically for use with Keithley's Model 2700 Multimeter/Data Acquisition System.

Card configuration — schematic

Figure B-10 shows a simplified schematic diagram of the Model 7702 module. As shown, the Model 7702 has channels that are grouped into two banks of twenty channels (forty channels total). Backplane isolation is provided for each bank. The first bank contains channels 1 through 20 while the second bank contains channels 21 through 40. Each channel of the 40-channel multiplexer card is wired with separate inputs for HI/LO providing fully isolated inputs. The Model 7702 also provides two channels of current input, Channels 41 and 42.

Although the Model 7702 relays are the latching type (relays hold their state even after power has been removed), all relay states are set to open a few seconds after either a power cycle or a *RST command is issued.

Connections to DMM functions are provided through the card backplane connector.

- Current provided through two protected channels (Channels 41 and 42).
- INPUT connections
- SENSE (Ω4 Wire) connections

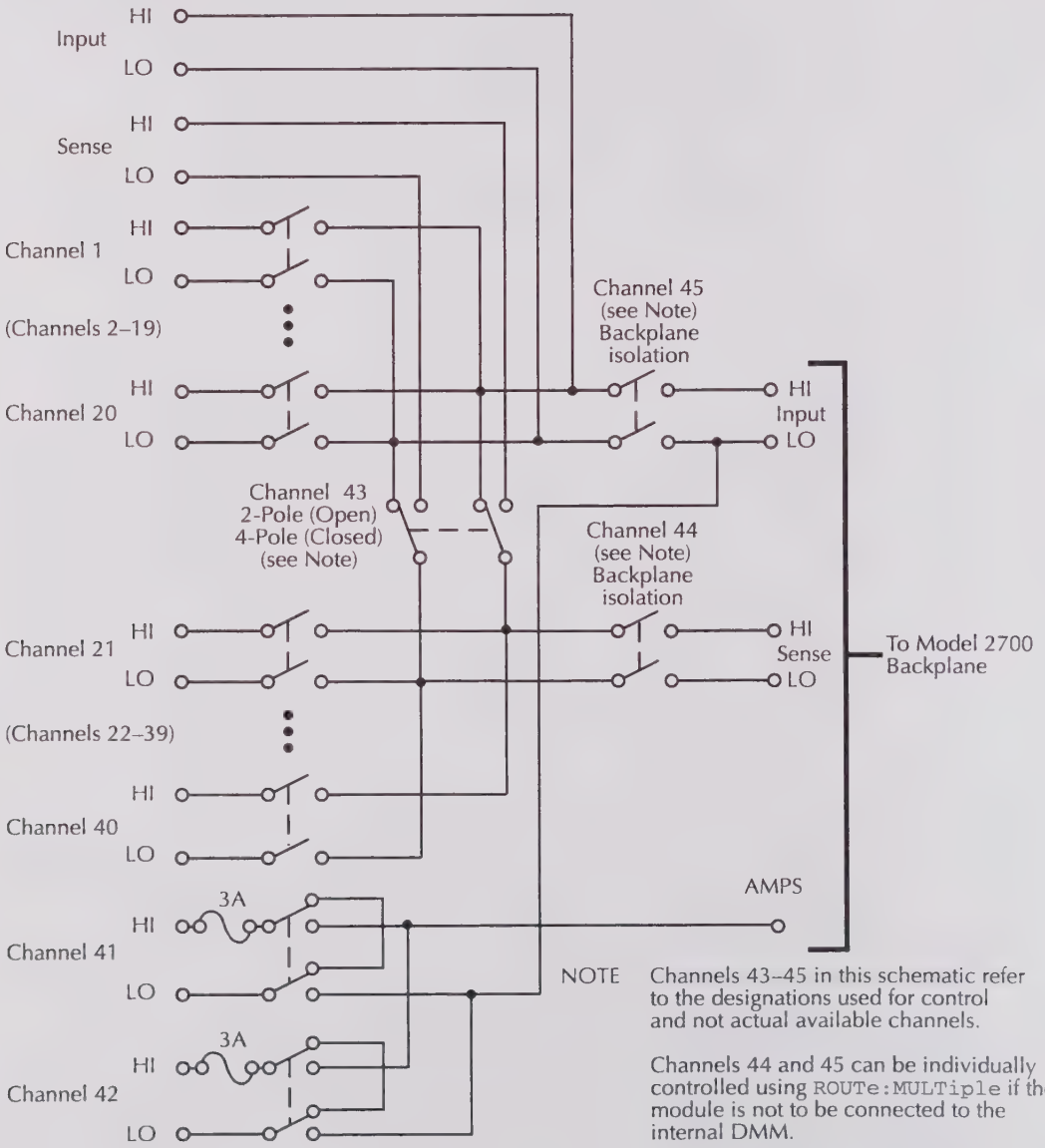
AMP and LO common connections to the DMM are also provided.

Channel 43 (2W/4W Configuration), Channel 44 (Sense Isolation), and Channel 45 (Input Isolation) are normally automatically configured by the 2700. However, by using the `ROUTE:MULT` commands (refer to Section 2), they can be manually configured.

NOTES *Connect 4-wire sense leads using channels 21–40.*

To disconnect channels 21–40 from channels 1–20, send:
`:ROUT:MULT:CLOS (@143)` *(note opposite logic)*

Figure B-10
Simplified schematic for Model 7702



NOTE Channels 43–45 in this schematic refer to the designations used for control and not actual available channels.

Channels 44 and 45 can be individually controlled using `ROUTe:MULTiple` if the module is not to be connected to the internal DMM.

For more information, refer to the `ROUTe:MULTiple` command section in the Model 2700 User's Manual.

When automatically configured for 4-wire measurements (including 4-wire Ω, RTD temperature, Ratio, and Channel average), the channels are paired as follows:

- CH1 and CH21
- CH2 and CH22
- CH3 and CH23
- CH4 and CH24
- CH5 and CH25
- CH6 and CH26
- CH7 and CH27
- CH8 and CH28
- CH9 and CH29
- CH10 and CH30
- CH11 and CH31
- CH12 and CH32
- CH13 and CH33
- CH14 and CH34
- CH15 and CH35
- CH16 and CH36
- CH17 and CH37
- CH18 and CH38
- CH19 and CH39
- CH20 and CH40

Card configuration — connections

WARNING **All wiring must be rated for the maximum voltage in the system. For example, if 1000V is applied to the front terminals of the Model 2700, the plug-in module wiring must be rated for 1000V.**

Figure B-11 shows how to access the screw terminals on the Model 7702. Channel designations for the screw terminals are contained in Figure B-12.

WARNING **Do not exceed the maximum specifications for the Model 7702 module. Refer to Appendix A for specifications.**

Figure B-11
Screw terminal access

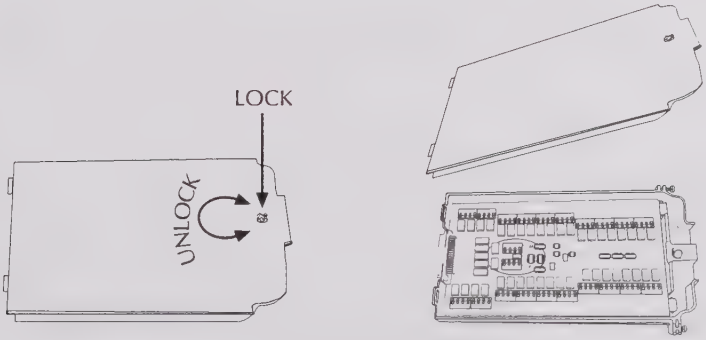
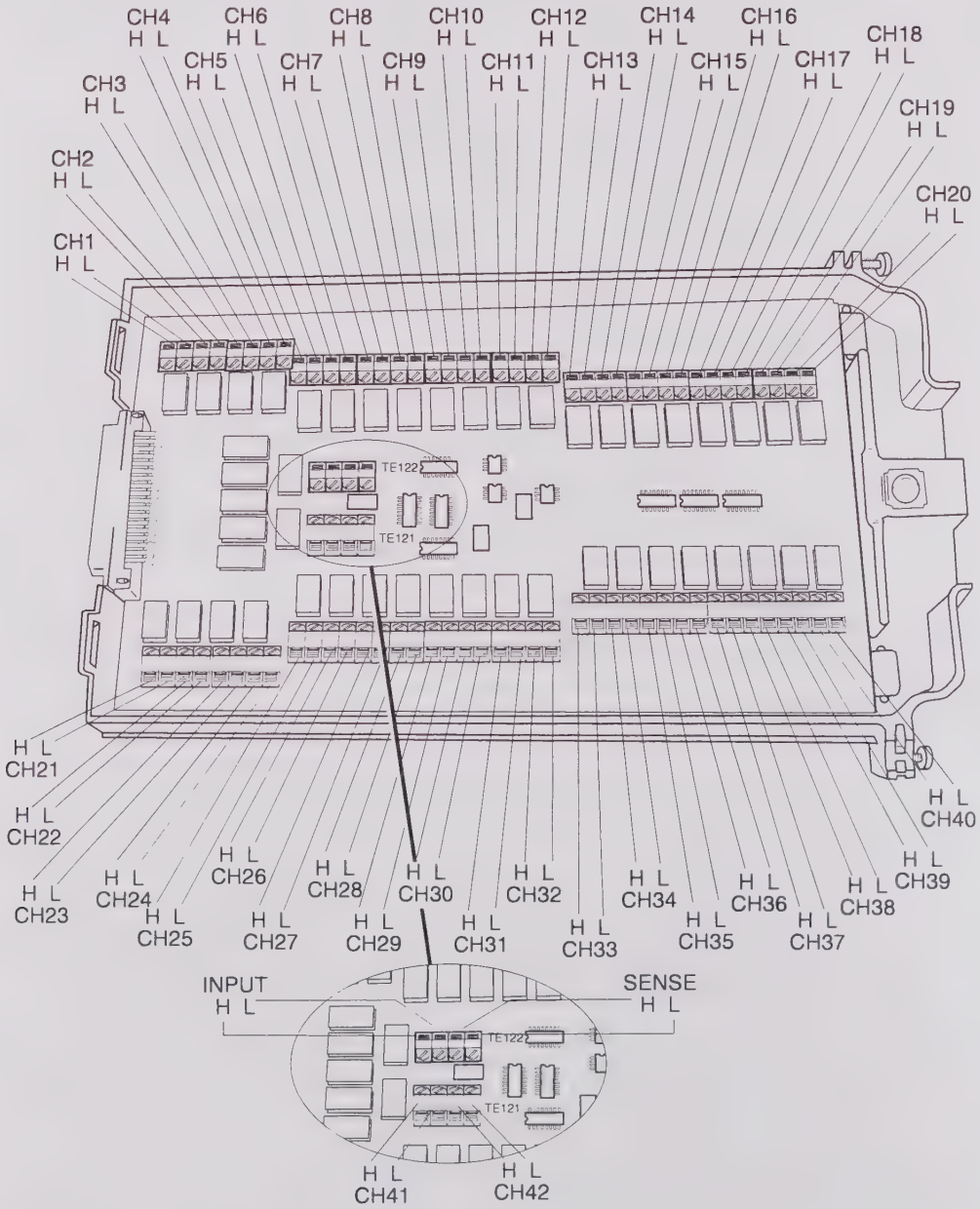


Figure B-12
Model 7702 screw terminal channel designations



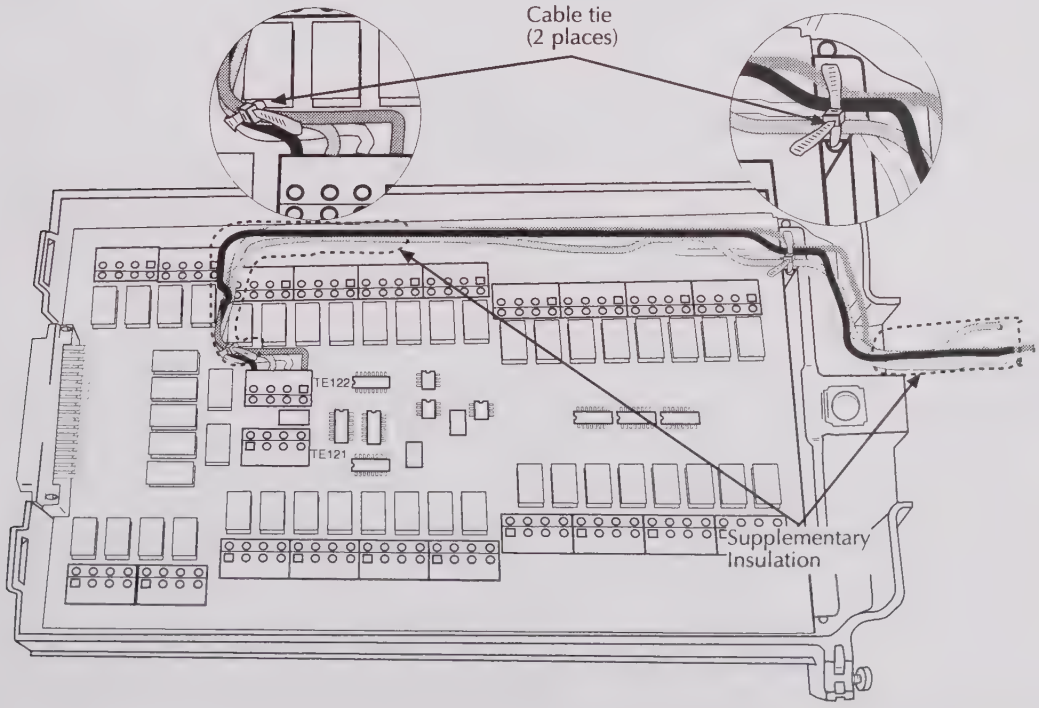
Wiring procedure

WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

Use the following procedure to wire the Model 7702 module. Make all connections using correct wire size (up to 20 AWG). Also, make sure to add supplementary insulation around the harness for voltages above 42V peak (see Figure B-13).

1. Make sure all power is discharged from the Model 7702 module.
2. Access the screw terminals (see Figure B-11).
3. Using a small flat-blade screwdriver, loosen terminal screws and install wires as desired. (Figure B-13 shows connections to channels 1 and 2.)
4. Route wire along wire-path and secure with cable ties as shown (2 places for each set of wires).
5. Fill-in a copy of the connection log (Table B-2) and affix it to the module cover.
6. Close and lock cover.

Figure B-13
Wire dressing



Typical connections

The following examples show typical wiring connections for the following types of measurements:

- Thermocouple connections, see Figure B-14
- Ω2-Wire and Thermistor connections, see Figure B-15
- Ω4-Wire and RTD connections, see Figure B-16
- Current (AC or DC), see Figure B-17
- Voltage (AC or DC), see Figure B-18

Figure B-14
Thermocouple connections

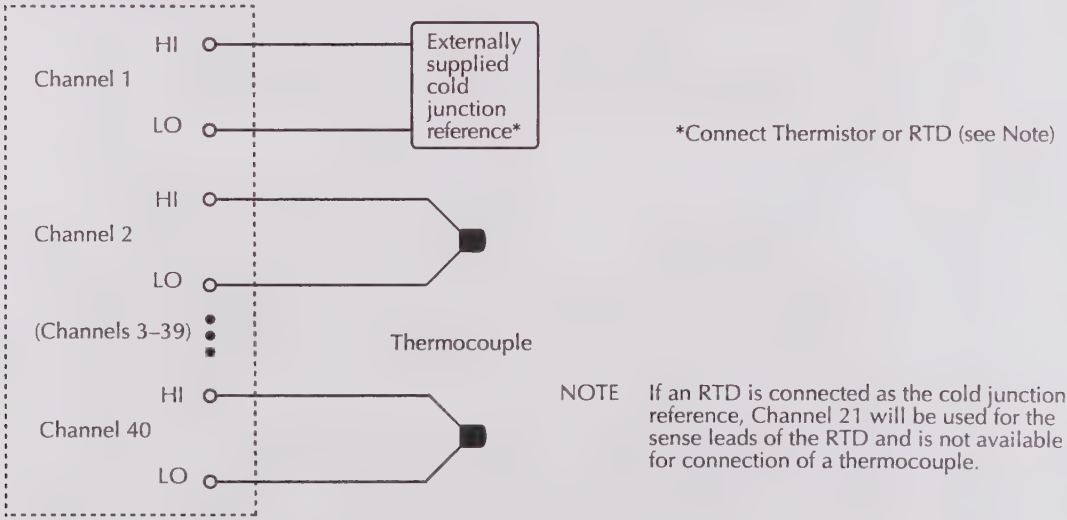
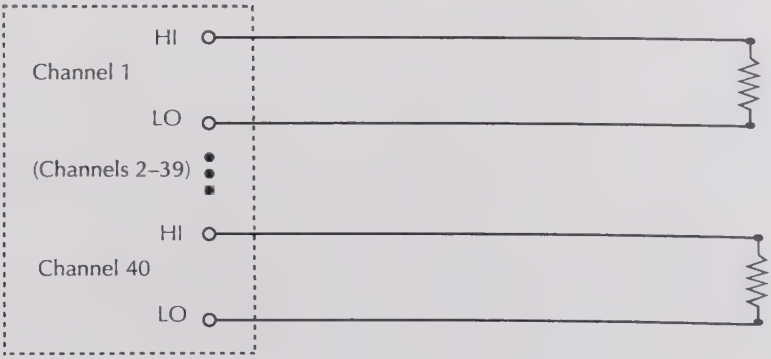

HI
Channel 1
LO
Externally supplied cold junction reference*
*Connect Thermistor or RTD (see Note)
HI
Channel 2
LO
(Channels 3–39)
Thermocouple
HI
Channel 40
LO
NOTE If an RTD is connected as the cold junction reference, Channel 21 will be used for the sense leads of the RTD and is not available for connection of a thermocouple.

Figure B-15
Ω2-Wire and thermistor connections



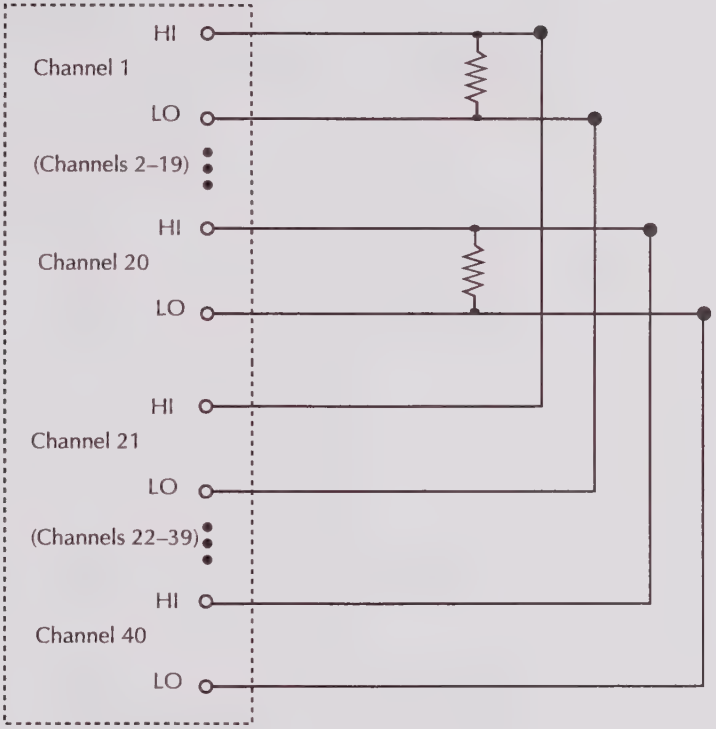


Figure B-16
Ω4-Wire and RTD connections

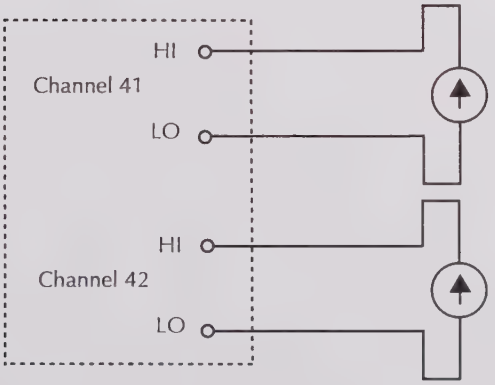


Figure B-17
Current connections (AC or DC)

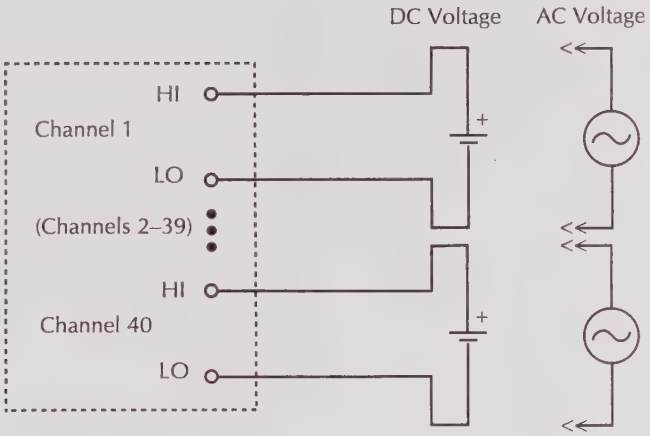


Figure B-18
Voltage connections (DC or AC)

Specifications

Full Model 7702 specifications are included in Appendix A of this manual.

Connection log

Make a copy of Table B-2 and affix it to the cover of the Model 7702. Use this to record connection information and channel descriptions as needed.

Table B-2
Connection log Model 7702

Channel		Color	Description	Description	Color	Channel	
INPUT	H						
	L						
SENSE	H						
	L						
CH21	H					H	CH1
	L					L	
CH22	H					H	CH2
	L					L	
CH23	H					H	CH3
	L					L	
CH24	H					H	CH4
	L					L	
CH25	H					H	CH5
	L					L	
CH26	H					H	CH6
	L					L	
CH27	H					H	CH7
	L					L	
CH28	H					H	CH8
	L					L	
CH29	H					H	CH9
	L					L	
CH30	H					H	CH10
	L					L	
CH31	H					H	CH11
	L					L	
CH32	H					H	CH12
	L					L	
CH33	H					H	CH13
	L					L	
CH34	H					H	CH14
	L					L	
CH35	H					H	CH15
	L					L	
CH36	H					H	CH16
	L					L	
CH37	H					H	CH17
	L					L	
CH38	H					H	CH18
	L					L	
CH39	H					H	CH19
	L					L	
CH40	H					H	CH20
	L					L	
AMPS41	H					H	AMPS42
	L					L	

Model 7703

The Model 7703 is a 32-channel high-speed differential multiplexer card with the following features:

- 2-wire or 4-wire Ω measurement (automatically pairs switches for four wire measurements — $n + 16$)
- Temperature applications (RTD, thermistor, thermocouple)
- High-speed reed relays
- 50-pin D-Shell connectors (2 × DB50)
- Designed specifically for use with Keithley's Model 2700 Multimeter/Data Acquisition System.

NOTE *The 50-pin D-Shell connector mates with Model 7788 (50-pin D-Shell connector kit).*

Card configuration — schematic

Figure B-19 shows a simplified schematic diagram of the Model 7703 module. As shown, the Model 7703 has channels that are grouped into two banks of sixteen channels (thirty-two channels total). Backplane isolation is provided for each bank. The first bank contains channels 1 through 16 while the second bank contains channels 17 through 32. Each channel of the 32-channel multiplexer card is wired with separate inputs for HI/LO providing fully isolated inputs.

The Model 7703 relays are non-latching relays (relays go to the open state after power has been removed).

Connections to DMM functions are provided through the card backplane connector.

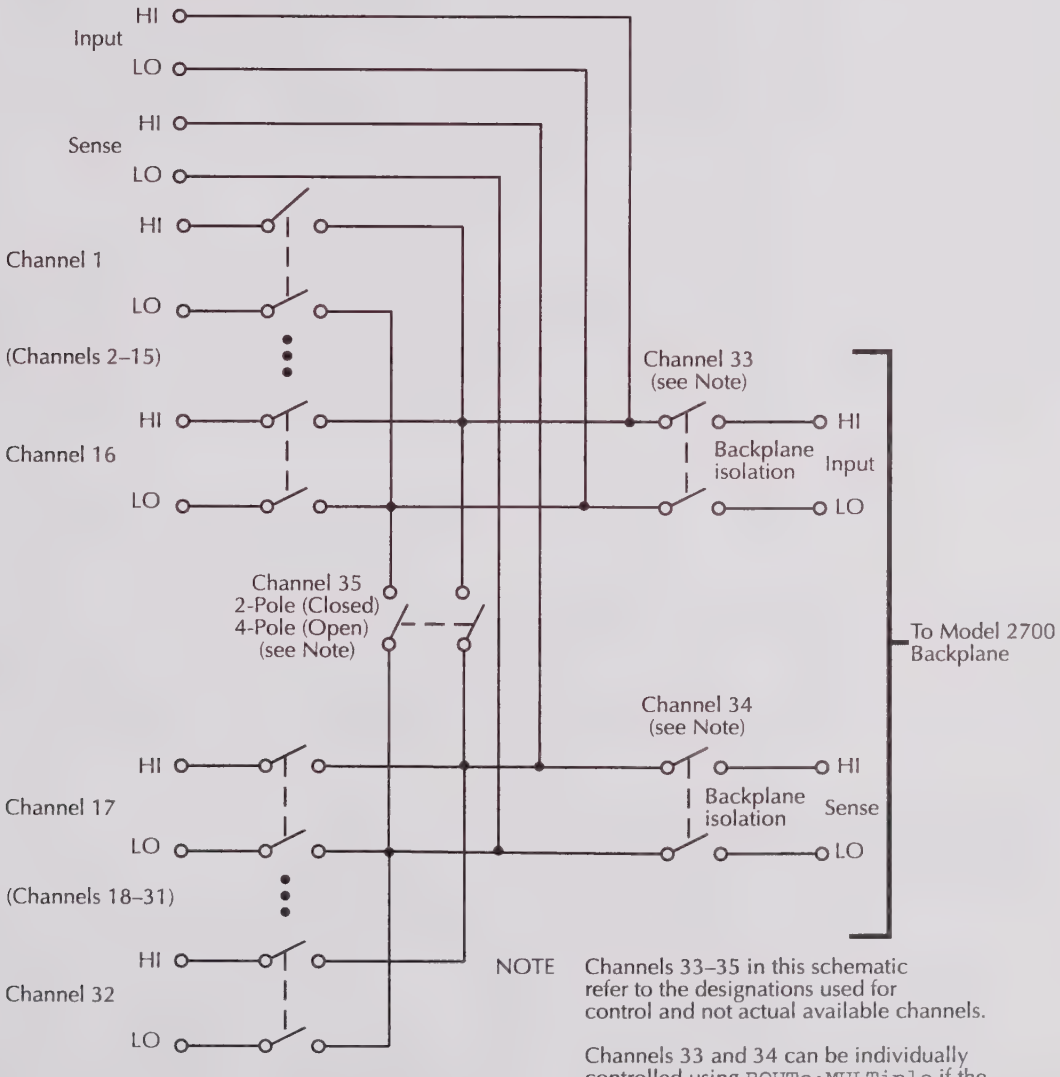
- INPUT connections
- SENSE (Ω4 Wire) connections

Channel 35 (2W/4W Configuration), Channel 34 (Sense Isolation), and Channel 33 (Input Isolation) are normally automatically configured by the 2700. However, by using the `:ROUT:MULT:` commands (refer to Section 2), they can be manually configured.

When automatically configured for 4-wire measurements, the channels are paired as follows:

- CH1 and CH17
- CH2 and CH18
- CH3 and CH19
- CH4 and CH20
- CH5 and CH21
- CH6 and CH22
- CH7 and CH23
- CH8 and CH24
- CH9 and CH25
- CH10 and CH26
- CH11 and CH27
- CH12 and CH28
- CH13 and CH29
- CH14 and CH30
- CH15 and CH31
- CH16 and CH32

Figure B-19
Simplified schematic for Model 7703



NOTE Channels 33–35 in this schematic refer to the designations used for control and not actual available channels.

Channels 33 and 34 can be individually controlled using `ROUTe:MULTiple` if the module is not to be connected to the internal DMM.

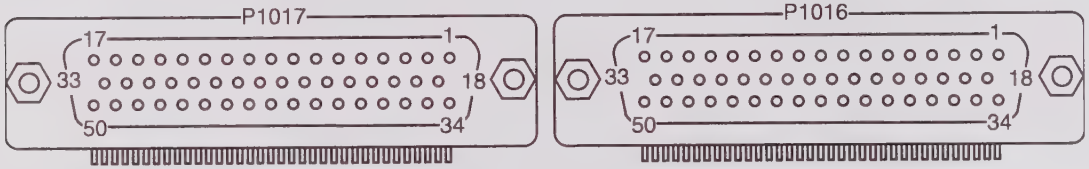
For more information, refer to the `ROUTe:MULTiple` command section in the Model 2700 User's Manual.

Card configuration — connections

Figure B-20 shows the pinouts for the Model 7703 rear panel connectors. Channel designations for the pins are contained in Table B-3.

WARNING **Do not exceed the maximum specifications for the Model 7703 module. Refer to Appendix A for specifications.**

Figure B-20
Rear view—Model 7703 pinouts (P1016 and P1017)



NOTE *The 50-pin D-Shell connectors mate with Model 7788 (50-pin D-Shell connector kit).*

Make all connections using correct wire size (up to 20 AWG). Also, make sure to add supplementary insulation around the harness for voltages above 42V peak (see Figure B-21).

WARNING **If both connectors (P1017 and P1016) are not used, install the extra Model 7788 50-pin D-shell as a plug on the open connector (see Figure B-21). If the connector is left open, an electrical shock hazard may be present.**

Figure B-21
Supplementary insulation and plugging an unused connector

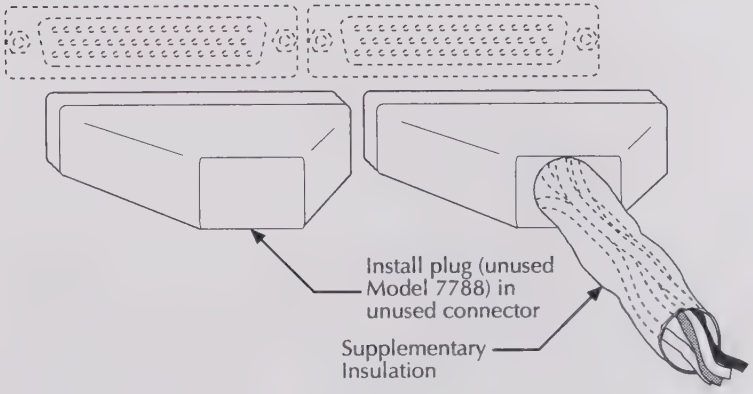


Table B-3
Model 7703 channel designations

P1016					
Pin	CH	Pin	CH	Pin	CH
1	Sense HI	26	5 HI	38	19 HI
2	Sense LO	27	5 LO	39	19 LO
4	Input HI	28	6 HI	40	20 HI
6	Input LO	29	6 LO	41	20 LO
18	1 HI	30	7 HI	42	21 HI
19	1 LO	31	7 LO	43	21 LO
20	2 HI	32	8 HI	44	22 HI
21	2 LO	33	8 LO	45	22 LO
22	3 HI	34	17 HI	46	23 HI
23	3 LO	35	17 LO	47	23 LO
24	4 HI	36	18 HI	48	24 HI
25	4 LO	37	18 LO	49	24 LO

P1017					
Pin	CH	Pin	CH	Pin	CH
18	9 HI	30	15 HI	42	29 HI
19	9 LO	31	15 LO	43	29 LO
20	10 HI	32	16 HI	44	30 HI
21	10 LO	33	16 LO	45	30 LO
22	11 HI	34	25 HI	46	31 HI
23	11 LO	35	25 LO	47	31 LO
24	12 HI	36	26 HI	48	32 HI
25	12 LO	37	26 LO	49	32 LO
26	13 HI	38	27 HI		
27	13 LO	39	27 LO		
28	14 HI	40	28 HI		
29	14 LO	41	28 LO		

Wiring procedure

WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

Use the following procedure in conjunction with wiring information provided with the connector to wire the Model 7703 module. Make all connections using correct wire size (refer to the Model 7788 documentation for specific wiring instructions).

WARNING **All wiring must be rated for the maximum voltage in the system. For example, if 1000V is applied to the front terminals of the Model 2700, the plug-in module wiring must be rated for 1000V.**

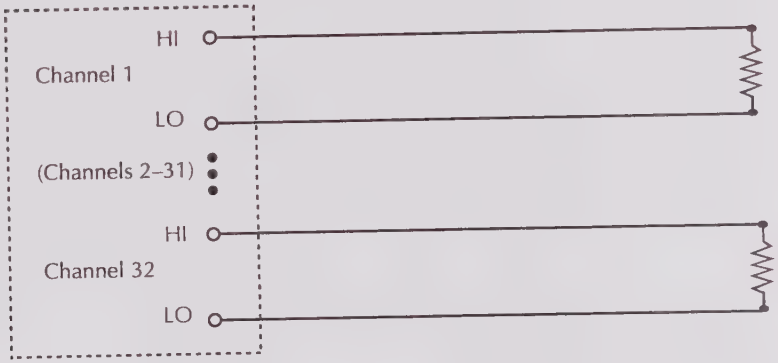
1. Make sure all power is discharged from the Model 7703 module.
2. Fill-in a copy of the connection log (Table B-4) and affix it to the module cover.

Typical connections

The following examples show typical wiring connections for the following types of measurements:

- Ω2-Wire and Thermistor connections, see Figure B-22
- Ω4-Wire and RTD connections, see Figure B-23
- Voltage (AC or DC), see Figure B-24

Figure B-22
Ω2-Wire and Thermistor connections



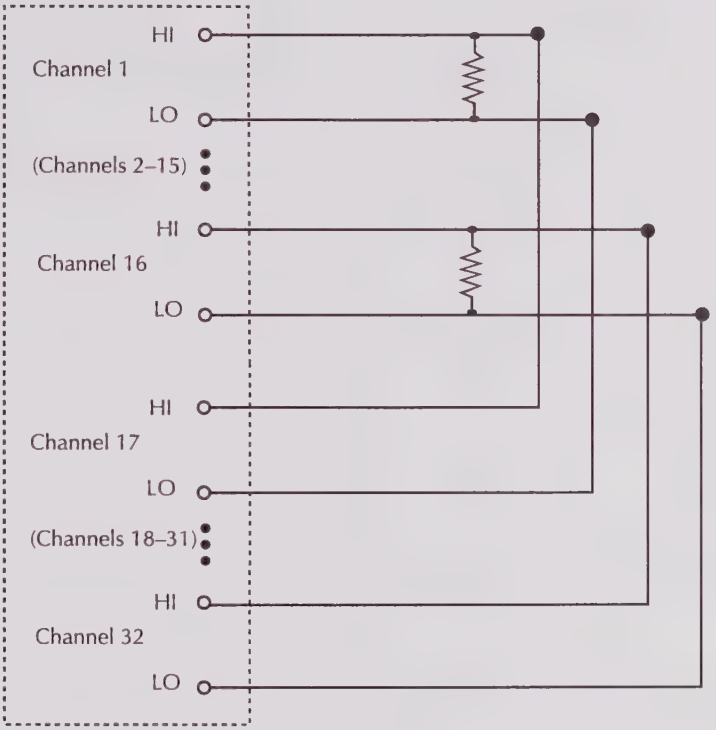


Figure B-23
Ω4-Wire and RTD connections

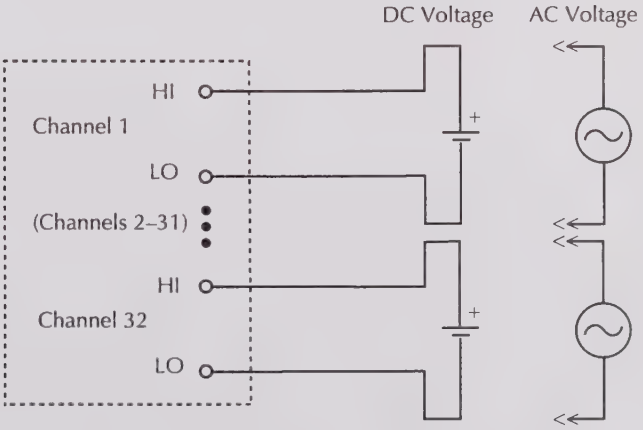


Figure B-24
Voltage connections (DC or AC)

Specifications

Full Model 7703 specifications are included in Appendix A of this manual.

Connection log

Make a copy of Table B-4 and affix it to the cover of the Model 7703. Use this to record connection information and channel descriptions as needed.

Table B-4
Connection log Model 7703

Channel		Color	Description	Description	Color	Channel	
INPUT	H						
	L						
SENSE	H						
	L						
CH1	H					H	CH17
	L					L	
CH2	H					H	CH18
	L					L	
CH3	H					H	CH19
	L					L	
CH4	H					H	CH20
	L					L	
CH5	H					H	CH21
	L					L	
CH6	H					H	CH22
	L					L	
CH7	H					H	CH23
	L					L	
CH8	H					H	CH24
	L					L	
CH9	H					H	CH25
	L					L	
CH10	H					H	CH26
	L					L	
CH11	H					H	CH27
	L					L	
CH12	H					H	CH28
	L					L	
CH13	H					H	CH29
	L					L	
CH14	H					H	CH30
	L					L	
CH15	H					H	CH31
	L					L	
CH16	H					H	CH32
	L					L	

C
Model 7705

Introduction

WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

This section contains information specific to the Model 7705 control module. For Model 7700, 7702, and 7703 modules, refer to Appendix B; for Model 7706 modules, refer to Appendix D.

If you have any questions after reviewing this information, please contact your local Keithley representative or call one of our Applications Engineers at 1-800-348-3735 (U.S. and Canada only). Worldwide phone numbers are listed at the front of this manual.

Model 7705

The Model 7705 is a 40-channel single-pole relay module with the following features:

- 40 Independent Form A switches
- Quick-disconnect 50 pin D-shell connector (2 × DB50)
- Designed specifically for use with Keithley's Model 2700 Multimeter/Data Acquisition System.

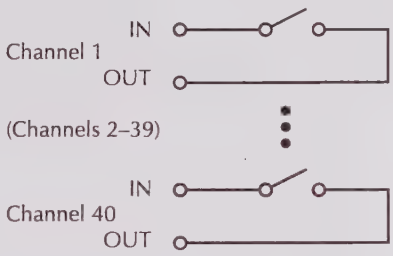
Card configuration — schematic

Figure C-1 shows a simplified schematic diagram of the Model 7705 module. As shown, the Model 7705 has channels that are grouped into two banks of twenty channels (forty channels total). The first bank contains channels 1 through 20 while the second bank contains channels 21 through 40. Each channel of the 40-channel single-pole relay module is wired with separate inputs and outputs providing fully isolated channels.

Keep the following in mind when using the Model 7705 module:

- No channels are connected to the internal DMM (the channels cannot be connected to the backplane).
- This card should only be used with `ROUT:MULT`, since `ROUT:CLOS` <clist> will open up every other channel in the 2700 (see Section 2).
- Although the Model 7705 relays are the latching type (relays hold their state even after power has been removed), all relay states are set to open a few seconds after either a power cycle or a *RST command is issued.

Figure C-1
Simplified schematic for Model 7705



All channels are normally controlled using the :ROUT:MULT commands (refer to Section 2). Although the ◀ / ▶ keys on the Model 2700 do not close channels on this card, the CLOSE menu will still allow channels to be closed. Trying to cycle through channels with the ◀ / ▶ keys generates the error message "NO MEAS CARD" if only 7705 cards are in place. If a 7705 channel is closed using the CLOS key or OUT:CLOS command, then the ◀ / ▶ arrows will also generate the same error message even if the card in the other slot is a valid measurement card.

If the "NO MEAS CARD" error message is generated, the ◀ / ▶ keys will not function. To make the arrow keys function again, first open the 7705 channels with the OPEN key or send a ROUT:OPEN:ALL command. This restriction does not apply if channels on the 7705 were closed with the ROUT:MULT:CLOS command.

Card configuration — connections

WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

Figure C-2 shows both of the Model 7705 DB-50 rear connectors. Channel designations for the pinouts are contained in Table C-1.

WARNING **Do not exceed the maximum specifications for the Model 7705 module. Refer to Appendix A for specifications.**

NOTE *When looking at the rear connectors of the Model 7705 module, the connector on the left is P1000 and the connector on the right is P1001.*

Figure C-2
Model 7705 pinouts

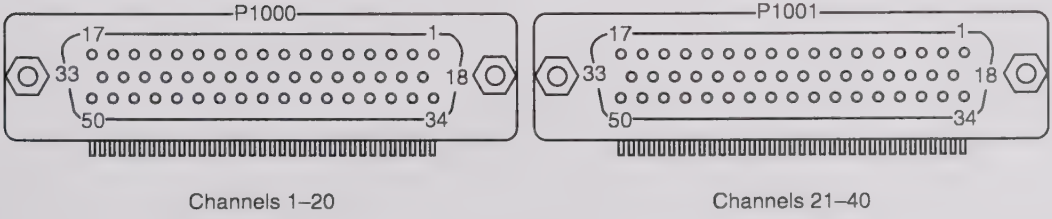


Table C-1
Model 7705 channel designations

P1000					
CH	PIN	CH	PIN	CH	PIN
1 IN	6	8 IN	25	15 IN	39
1 OUT	8	8 OUT	26	15 OUT	40
2 IN	10	9 IN	27	16 IN	41
2 OUT	12	9 OUT	28	16 OUT	42
3 IN	14	10 IN	29	17 IN	43
3 OUT	16	10 OUT	30	17 OUT	44
4 IN	17	11 IN	31	18 IN	45
4 OUT	18	11 OUT	32	18 OUT	46
5 IN	19	12 IN	33	19 IN	47
5 OUT	20	12 OUT	34	19 OUT	48
6 IN	21	13 IN	35	20 IN	49
6 OUT	22	13 OUT	36	20 OUT	50
7 IN	23	14 IN	37		
7 OUT	24	14 OUT	38		

P1001					
CH	PIN	CH	PIN	CH	PIN
21 IN	6	28 IN	25	35 IN	39
21 OUT	8	28 OUT	26	35 OUT	40
22 IN	10	29 IN	27	36 IN	41
22 OUT	12	29 OUT	28	36 OUT	42
23 IN	14	30 IN	29	37 IN	43
23 OUT	16	30 OUT	30	37 OUT	44
24 IN	17	31 IN	31	38 IN	45
24 OUT	18	31 OUT	32	38 OUT	46
25 IN	19	32 IN	33	39 IN	47
25 OUT	20	32 OUT	34	39 OUT	48
26 IN	21	33 IN	35	40 IN	49
26 OUT	22	33 OUT	36	40 OUT	50
27 IN	23	34 IN	37		
27 OUT	24	34 OUT	38		

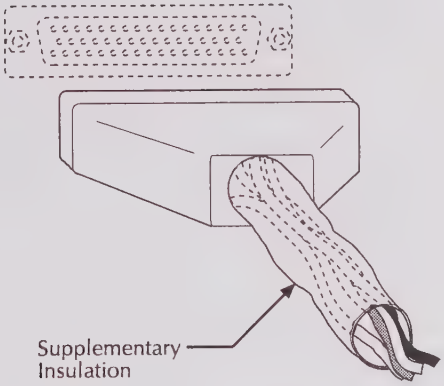
Typical connections

WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

CAUTION **To prevent damage to the card, do not exceed the maximum signal level specifications of the card. For reactive loads, be sure to use voltage clamping and current limiting as explained in the Reactive loads paragraph.**

Make all connections using correct wire size (up to 20 AWG). Also, make sure to add supplementary insulation around the harness for voltages above 42V peak. (see Figure C-3).

Figure C-3
Supplementary insulation



Maximum signal levels

CAUTION **To prevent overheating or damage to the relays, never exceed the following maximum signal levels: 300V (DC or RMS) between any two inputs or chassis, 60W (DC, resistive), 125VA (AC, resistive), or 2A switched.**

Reactive loads

Model 7705 operation is specified for resistive loads. Reactive loads require voltage clamping (for inductive loads) and current surge limiting (for capacitive loads) to prevent damage to the relays and to external circuitry.

Inductive loads — Inductive reaction voltage must be limited to less than 300V (DC or RMS). Also consider the load when determining the voltage limit. Clamping circuits that can be used are shown in Figure C-6.

Capacitive loads — The initial surge current from a capacitive reactive load must be limited. Figure C-7 shows circuits that can be used to limit current surges. To protect the relay, limit current to 2A. Also, make sure to consider the load when determining the current surge limit.

The following examples show typical wiring connections for the following:

- Typical connections—indicator lamp, alarm, and relay — Figure C-4
- Variable AC line/load test connections — Figure C-5
- Limiting inductive reaction voltage — Figure C-6
- Limiting capacitive reaction voltage — Figure C-7

WARNING **Make sure to add supplementary insulation around the harness for voltages above 42V peak.**

Figure C-4
Typical connections—indicator lamp, alarm, and relay

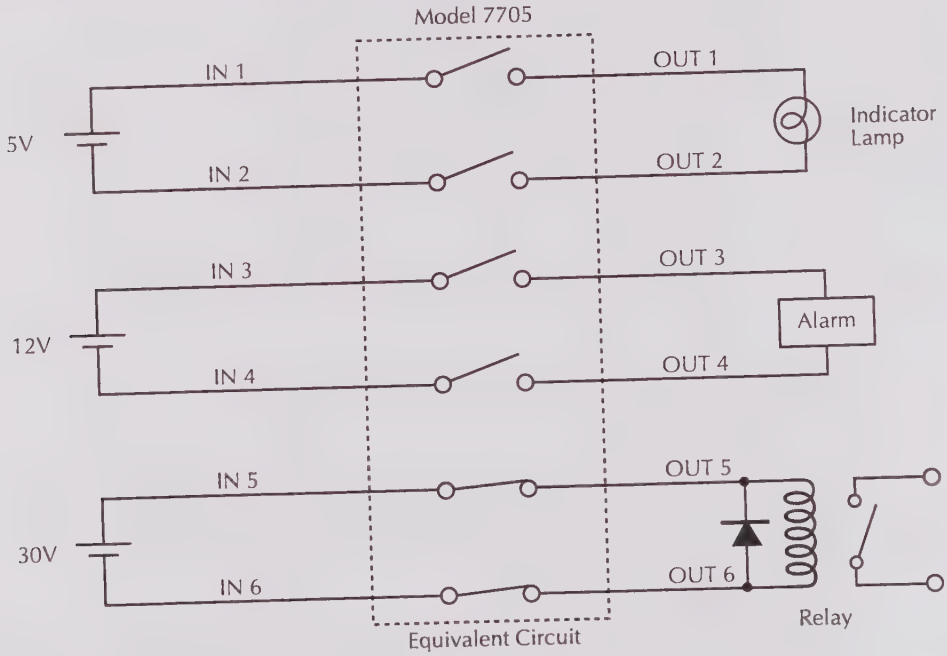
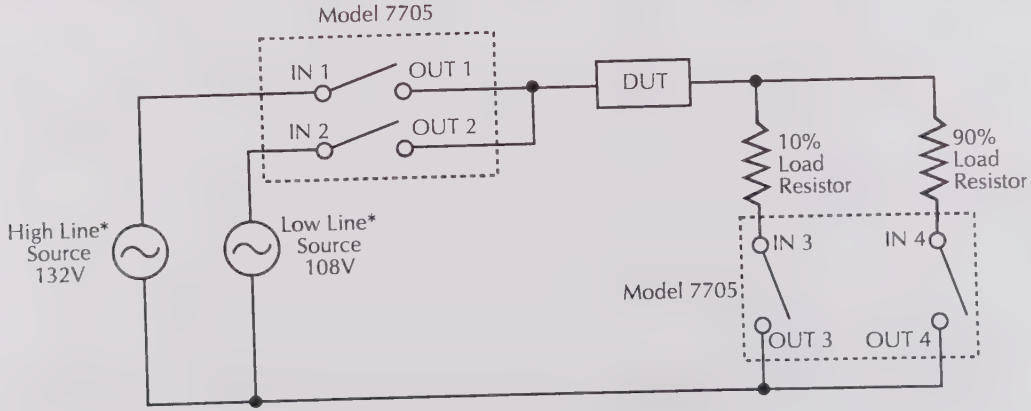


Figure C-5
Variable AC line/load test connections



CAUTION: Maximum switch current is 2A.

*Source is impedance limited from mains (Safety Category I signals).

Figure C-6
Limiting inductive reaction voltage

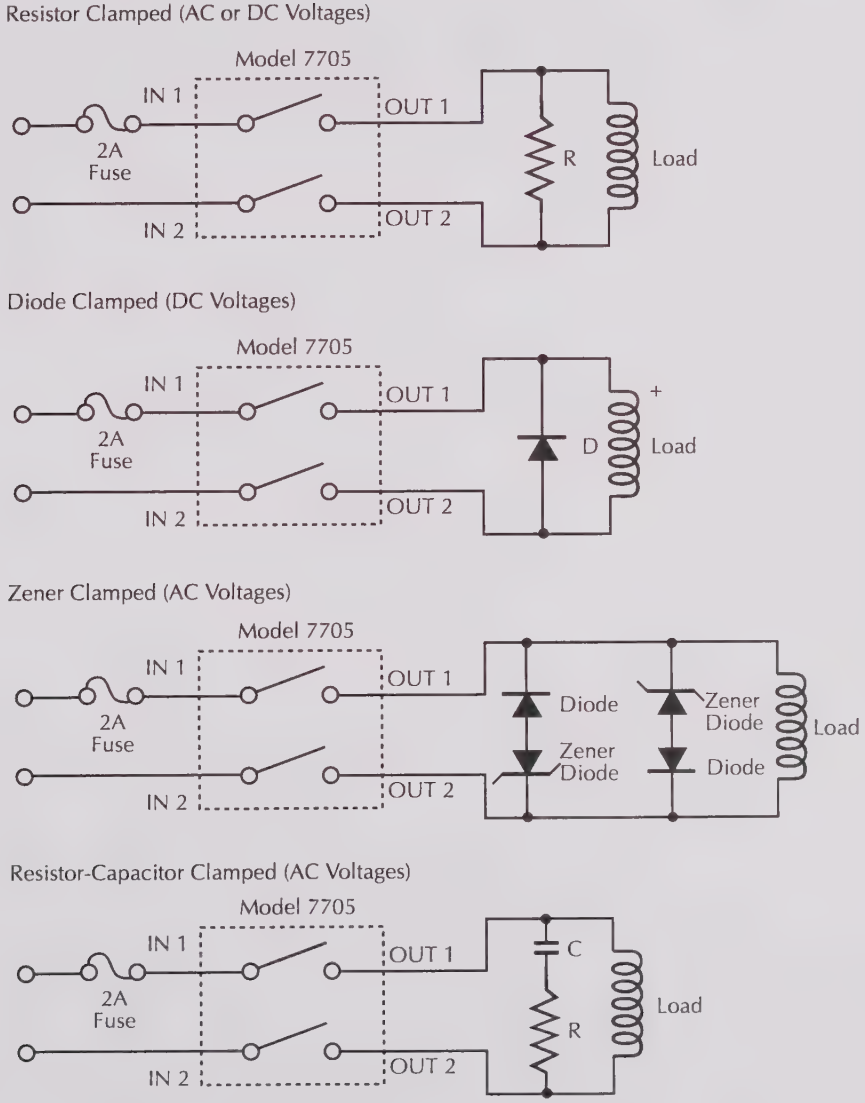
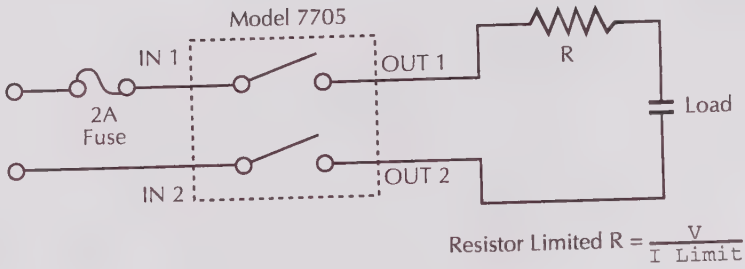
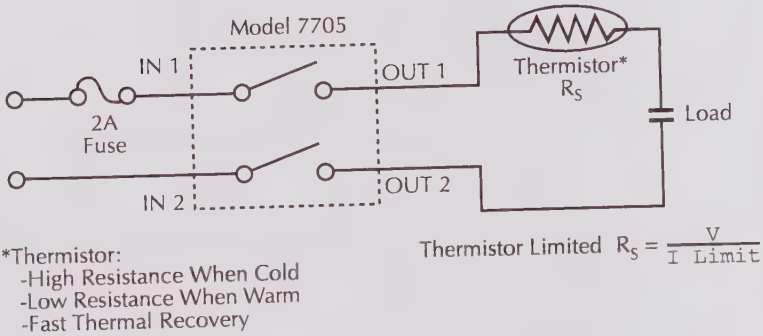


Figure C-7
Limiting capacitive reaction voltage





Specifications

Full Model 7705 specifications are included in Appendix A of this manual.

Connection log

Make a copy of Table C-2 and affix it to the cover of the Model 7705. Use this to record connection information and channel descriptions as needed.

Table C-2
Connection log Model 7705

NOTE *Refer to Table C-1 and Figure C-2 for pinouts.*

Channel		Color	Description	Description	Color	Channel	
1	IN					IN	21
	OUT					OUT	
2	IN					IN	22
	OUT					OUT	
3	IN					IN	23
	OUT					OUT	
4	IN					IN	24
	OUT					OUT	
5	IN					IN	25
	OUT					OUT	
6	IN					IN	26
	OUT					OUT	
7	IN					IN	27
	OUT					OUT	
8	IN					IN	28
	OUT					OUT	
9	IN					IN	29
	OUT					OUT	
10	IN					IN	30
	OUT					OUT	
11	IN					IN	31
	OUT					OUT	
12	IN					IN	32
	OUT					OUT	
13	IN					IN	33
	OUT					OUT	
14	IN					IN	34
	OUT					OUT	
15	IN					IN	35
	OUT					OUT	
16	IN					IN	36
	OUT					OUT	
17	IN					IN	37
	OUT					OUT	
18	IN					IN	38
	OUT					OUT	
19	IN					IN	39
	OUT					OUT	
20	IN					IN	40
	OUT					OUT	

D
Model 7706

Introduction

This section contains information specific to the Model 7706 module. For Model 7700, 7702, and 7703 modules, refer to Appendix B; for Model 7705 modules, refer to Appendix C.

If you have any questions after reviewing this information, please contact your local Keithley representative or call one of our Applications Engineers at 1-800-348-3735 (U.S. and Canada only). Worldwide phone numbers are listed at the front of this manual.

Connection

The Model 7706 is a 20-channel differential multiplexer card with the following features:

- 20 channels of analog input with 300V, 1A capacity; 60W, 125VA maximum
- 16 channels of digital output for output control
- One event counter/totalizer
- Two analog outputs (±12V @ 5mA with 16-bit programmability)
- 2-wire or 4-wire Ω measurement (automatically pairs switches for four wire measurements — $n + 10$)
- Temperature applications (RTD, thermistor, thermocouple)
- Built-in automatic cold junction reference (CJC)
- Screw terminal connections
- Designed specifically for use with Keithley's Model 2700 Multimeter/Data Acquisition System

Card configuration—schematic

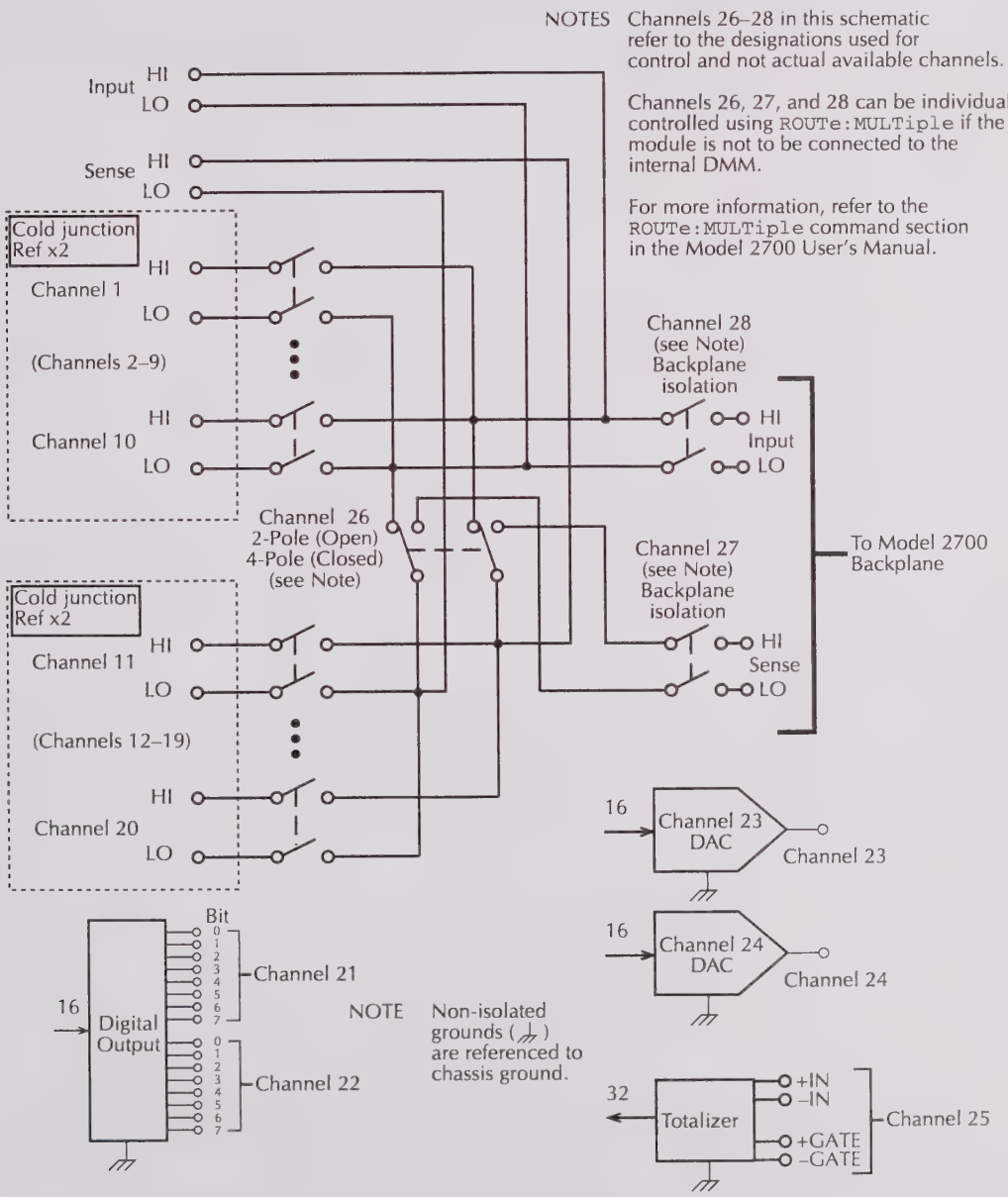
Figure D-1 shows a simplified schematic diagram of the Model 7706 module. As shown, the Model 7706 has channels that are grouped into two banks of ten channels (twenty channels total). Backplane isolation is provided for each bank. Each bank also includes separate cold junction reference points. The first bank contains channels 1 through 10 while the second bank contains channels 11 through 20. Each channel of the 20-channel multiplexer card is wired with separate inputs for HI/LO providing fully isolated inputs.

NOTE *Although the Model 7706 relays are the latching type (relays hold their state even after power has been removed), all relay states are set to open a few seconds after either a power cycle or a *RST command is issued.*

Connections to DMM functions are provided through the card backplane connector for the following:

INPUT connections
SENSE (Ω4-wire) connections

Figure D-1
Simplified schematic for Model 7706



Channels 21–22 (digital output), 23–24 (analog output), and 25 (Totalizer) are controlled either over the bus or from the front panel. The grounds for these channels are non-isolated. Detailed information on each channel is contained later in this section.

Channel 26 (2W/4W Configuration), Channel 27 (Sense Isolation), and Channel 28 (Input Isolation) are normally automatically configured by the 2700. However, by using the `:ROUT:MULT:` commands (refer to Section 2), they can be manually configured.

NOTES *Connect 4-wire sense leads using channels 11–20.*

To disconnect channels 11–20 from channels 1–10, send:

`:ROUT:MULT:CLOS (@126)` *(note opposite logic)*

When automatically configured for 4-wire measurements (including 4-wire Ω, RTD temperature, ratio, and channel average) the channels are paired as follows:

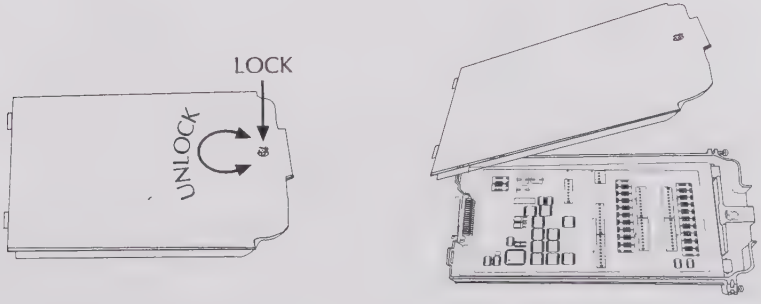
CH1 and CH11	CH6 and CH16
CH2 and CH12	CH7 and CH17
CH3 and CH13	CH8 and CH18
CH4 and CH14	CH9 and CH19
CH5 and CH15	CH10 and CH20

Card configuration—connections

WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

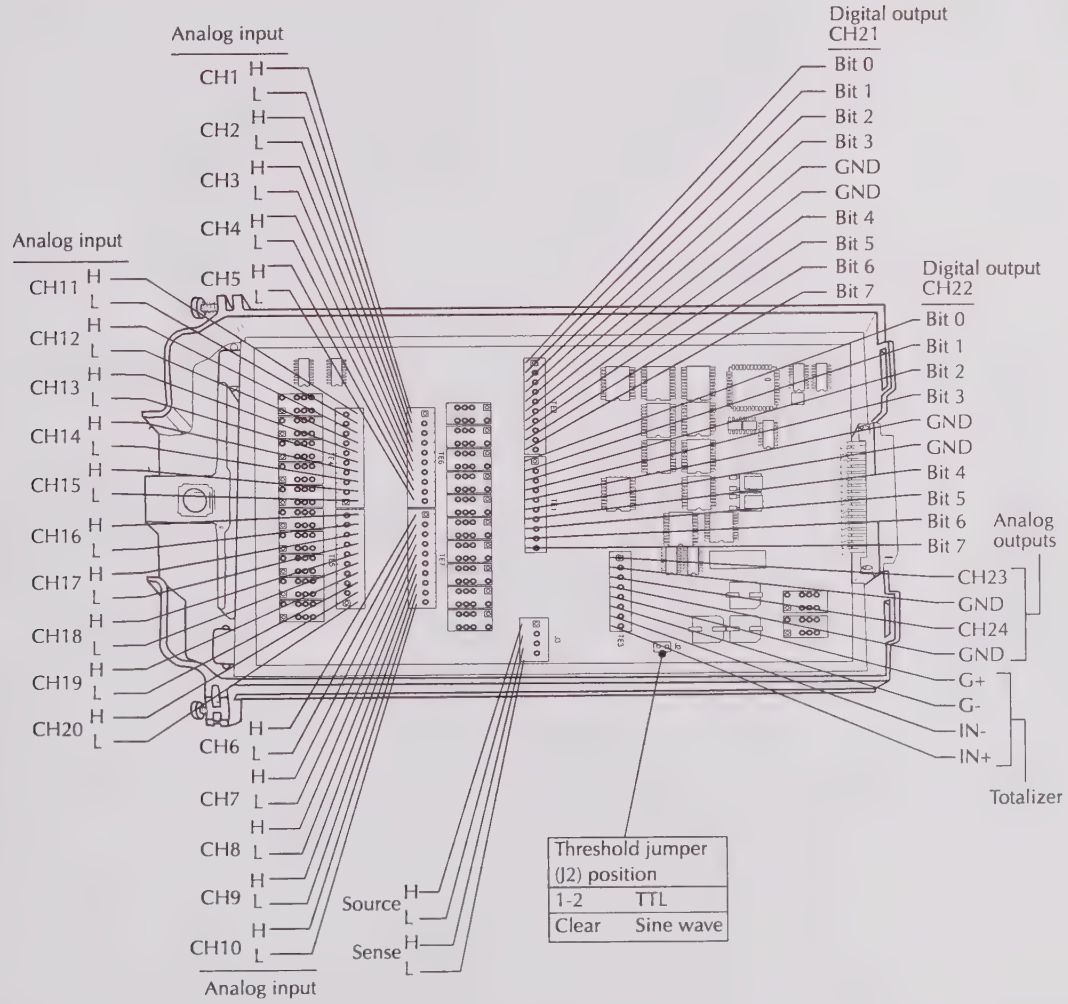
Figure D-2 shows how to access the screw terminals on the Model 7706. Channel designations for the screw terminals are contained in Figure D-3.

Figure D-2
Screw terminal access



WARNING **Do not exceed the maximum specifications for the Model 7706 module. Refer to Appendix A for specifications.**

Figure D-3
Model 7706 screw terminal channel designations



Wiring procedure

WARNING **The information in this section is intended for qualified service personnel. Do not attempt to perform this procedure unless qualified to do so.**

Use the following procedure to wire the Model 7706 module. Make all connections using correct wire size (up to 22 AWG). Also, make sure to add supplementary insulation around the harness for voltages above 42V peak (see Figure D-4).

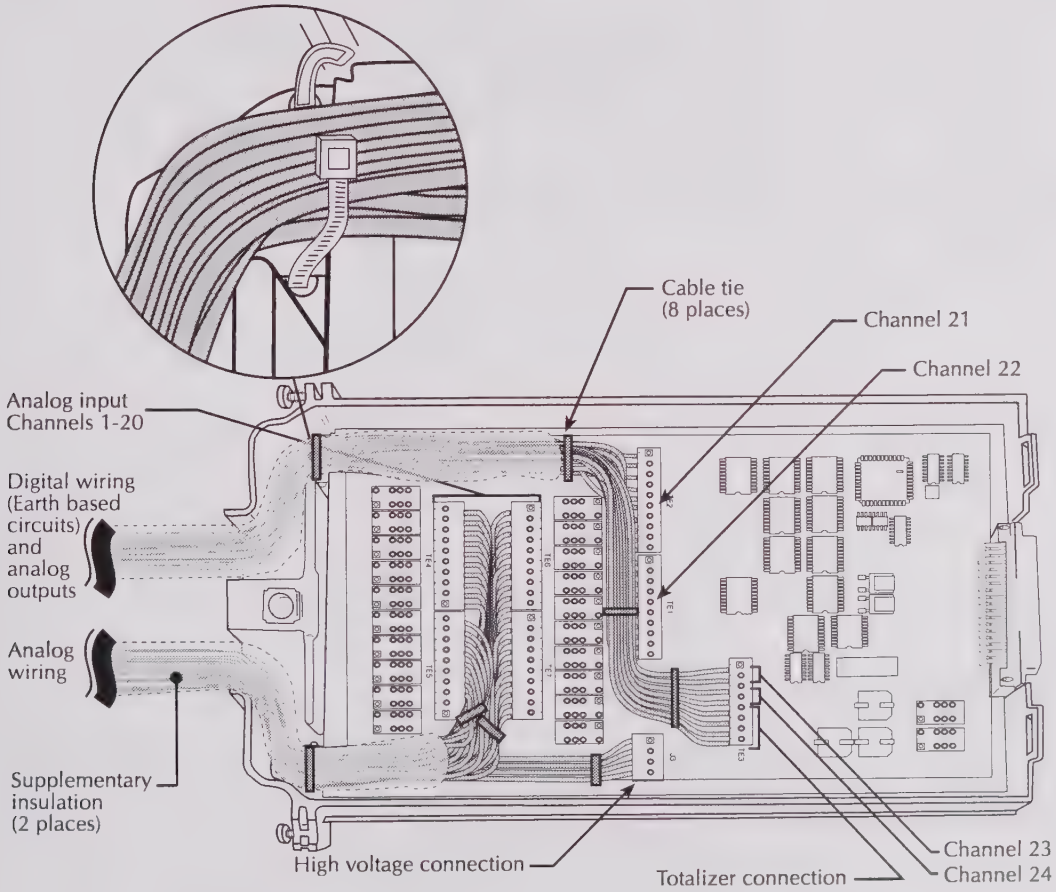
WARNING **All wiring must be rated for the maximum voltage in the system. For example, if 1000V is applied to the front terminals of the Model 2700, the plug-in module wiring must be rated for 1000V.**

1. Make sure all power is discharged from the Model 7706 module.
2. Access the screw terminals (see Figure D-2).
3. Using a small flat-blade screwdriver, loosen terminal screws and install wires as desired. (Figure D-4 shows connections to all channels).
4. Route wire along wire-path and secure with cable ties as shown (see Figure D-4).
5. Fill in a copy of the connection log (Table D-1) and affix it to the module cover.
6. Close and lock cover.

WARNING **The Model 7706 Module provides connections for both high voltage analog measurements as well as digital earth based circuits. Make sure to install and maintain double insulation between the analog and digital circuit wiring using supplementary insulation as required (see Figure D-4).**

Figure D-4
Wire dressing—fully wired module

Note Secure wiring to 7706 by using cable ties through cable tie holes.



Typical connections (channels 1–20)

The following examples show typical wiring connections for the following types of measurements:

- Thermocouple connections, see Figure D-5
- Ω2-wire and thermistor connections, see Figure D-6
- Ω4-wire and RTD connections, see Figure D-7
- Voltage (AC or DC), see Figure D-8

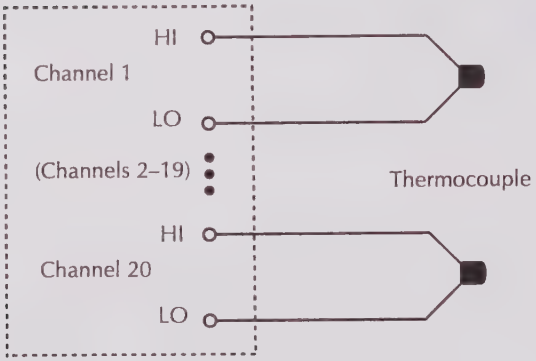


Figure D-5
Thermocouple connections

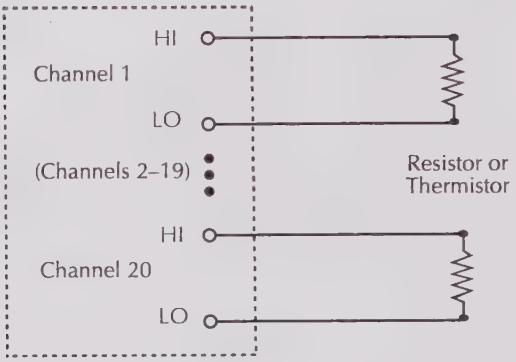


Figure D-6
Ω2-wire and thermistor connections

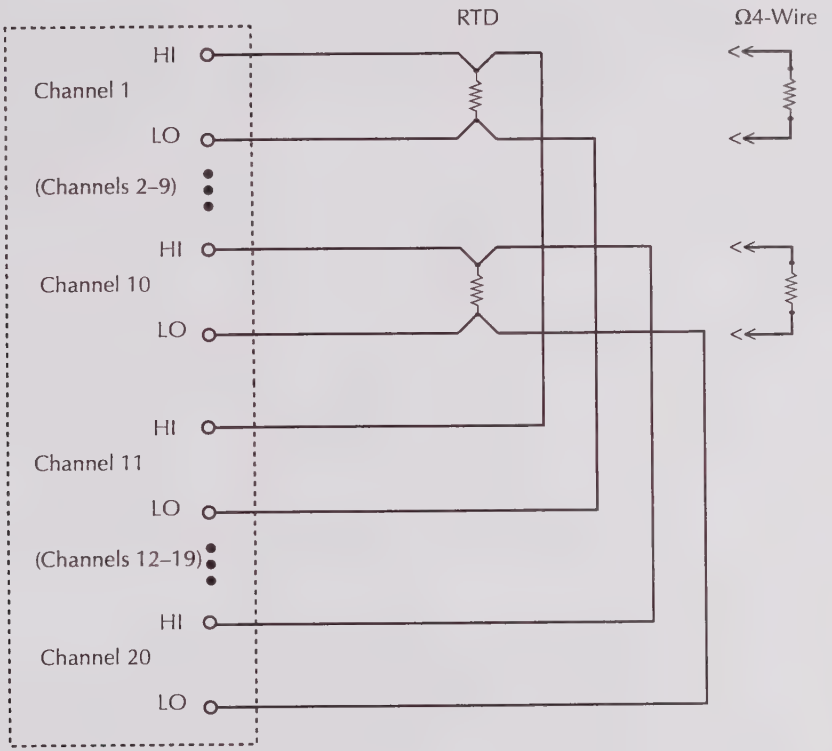


Figure D-7
Ω4-wire and RTD connections

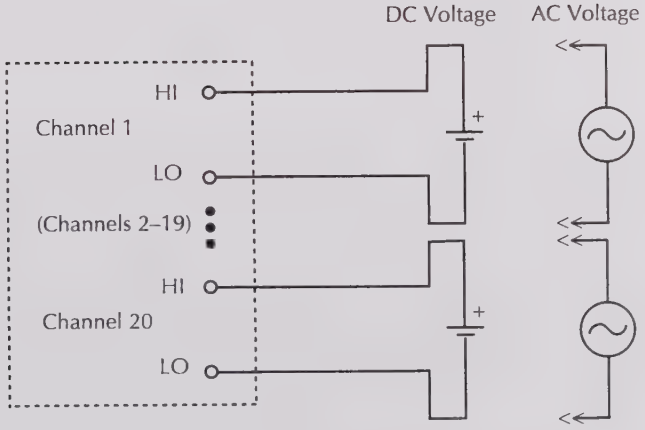
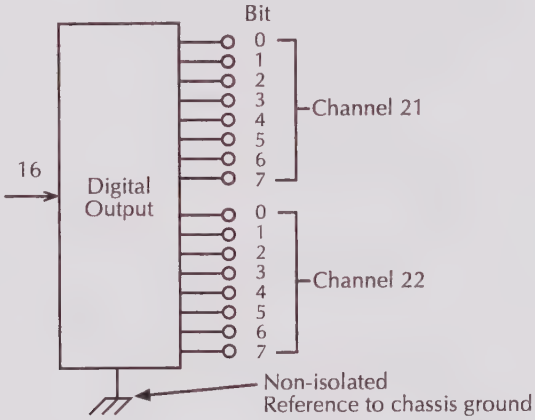


Figure D-8
Voltage connections (DC or AC)

Digital outputs (channels 21–22)

Use the Model 7706 digital outputs to control indicators, fixtures, switches, solenoids, loads, relays, etc. Figure D-9 shows a simplified schematic of the digital output.

Figure D-9
Simplified schematic of digital output



Setting the digital output in 8-bit (byte)

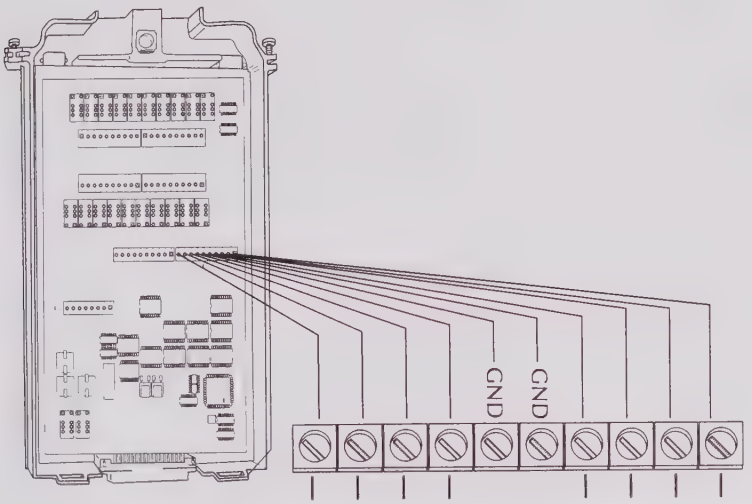
To set the digital output, send the decimal equivalent of the binary pattern desired. Keep in mind that on each port, bit 7 is the most significant bit (MSB) and bit 0 is the least significant bit (LSB). This makes the pin 1 screw terminal of each digital port (TE2 and TE1) the LSB and pin 10 the MSB.

NOTES *TE2 is Channel 21 and TE1 is Channel 22.*

Pins 5 and 6 on each digital port are ground.

To find the decimal equivalent of the binary pattern, first determine the pattern mapped to the screw terminals on the desired digital output (refer to the example contained in Figure D-10). Setting a bit to a logic '1' effectively sets the screw terminal to +5V while setting it to a logic '0' sets the screw terminal to 0V. Then, for each screw terminal (or bit position), multiply the binary value (either a 1 or a 0) by the decimal weight (see Figure D-10). The sum of the products is the decimal equivalent value of the binary pattern. This decimal value can be either sent over the bus (as in the example) or using the front panel of the Model 2700. To send it over the front panel: under the SHIFT->CARD menu, key in the decimal value (138) for the menu item "DIGOUT1: XXX". Refer to Figure D-11 for a sample on Channel 22.

Figure D-10
Sample digital output for Channel 21


GND
GND
Digital output CH21
10 9 8 7 4 3 2 1
Screw terminal number
B7 B6 B5 B4 B3 B2 B1 B0
Bit Position
0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1
Binary Value
(2^7) (2^6) (2^5) (2^4) (2^3) (2^2) (2^1) (2^0)
Weights
128 64 32 16 8 4 2 1
Equivalent decimal weight

Example:

Channel 21

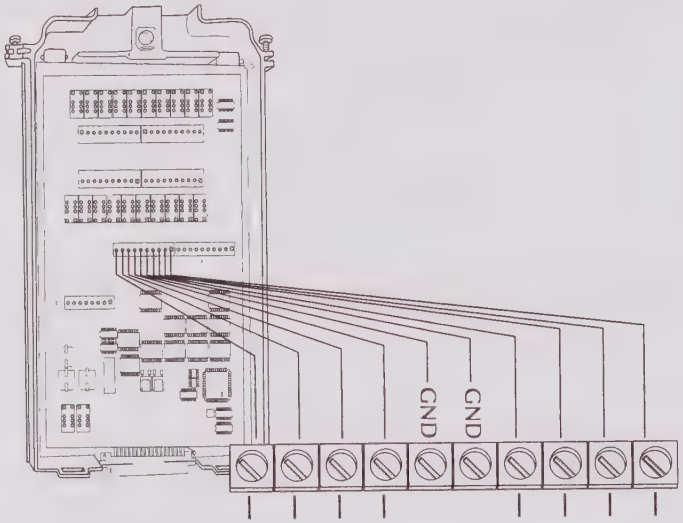
Multiply the binary values	1	0	0	0		1	0	1	0	Binary Value
by the decimal weight	128	64	32	16		8	4	2	1	Decimal weight
Add the products together	128 +	0 +	0 +	0	+	8 +	0 +	2 +	0	= 138 (this is the NRf value in the command)

Therefore, the command to send is:

```
OUTP:DIG:BYTE 138,(@121)
```

- Channel 21 of the Model 7706 in slot 1
- NRf value of 138 (specifies which terminals are 1 / 0)
- 8 bit
- Digital
- Output

Figure D-11
Sample digital output for Channel 22


GND
GND
Digital output CH22
10 9 8 7 4 3 2 1 Screw terminal number
B7 B6 B5 B4 B3 B2 B1 B0 Bit Position
0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 Binary Value
(2^7) (2^6) (2^5) (2^4) (2^3) (2^2) (2^1) (2^0) Weights
128 64 32 16 8 4 2 1 Equivalent decimal weight

Example:

Channel 22

	1	0	0	0		1	0	0	1
	10	9	8	7		4	3	2	1
Multiply the binary values	1	0	0	0		1	0	0	1
by the decimal weight	128	64	32	16		8	4	2	1
Add the products together	128 +	0 +	0 +	0	+	8 +	0 +	0 +	1

Binary Value

Decimal weight

= 137 (this is the NRf value in the command)

Therefore, the command to send is:

```
OUTP:DIG:BYTE 137,(@122)
```

- Channel 22 of the Model 7706 in slot 1
- NRf value of 137 (specifies which terminals are 1 / 0)
- 8 bit
- Digital
- Output

Setting the digital outputs in 16-bit (word)

NOTE *Setting the digital output in 16-bit (word) can be accomplished only over the bus (no front panel operation).*

To set the digital outputs in 16-bit, send the decimal equivalent of the binary pattern desired (similar to 8-bit). The binary pattern will be twice as long as the 8-bit pattern (requiring both digital output ports). Keep in mind that bit 15 is the most significant bit (MSB) and bit 0 is the least significant bit (LSB). This makes the pin 1 screw terminal of channel 21 (TE2) the LSB and the pin 10 screw terminal of channel 22 (TE1) the MSB.

To find the decimal equivalent of the binary pattern, first determine the pattern mapped to the screw terminals on the desired digital output (refer to the example contained in Figure D-12). Setting a bit to a logic '1' effectively sets the screw terminal to +5V while setting it to a logic '0' sets the screw terminal to 0V. Then, for each screw terminal (or bit position), multiply the binary value (either a 1 or a 0) by the decimal weight (see Figure D-12). The sum of the products is the decimal equivalent value of the binary pattern. This decimal value can be sent over the bus as in the example.

The digital output allows the use of an external power supply up to 42V. Refer to Figure D-13.

Inductive loads

Model 7706 operation is specified for resistive loads. Reactive (inductive) loads require voltage clamping. Before using inductive loads, take adequate circuit protection measures (refer to Appendix C).

Figure D-12
Sample sending a digital output word (16 bit)

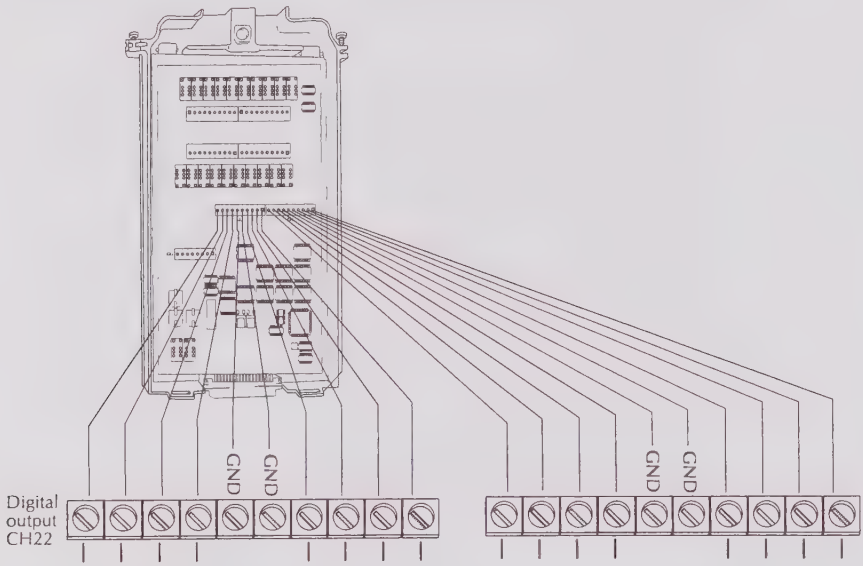

GND
GND
GND
GND
Digital output CH22
Digital output CH21
7 6 5 4 3 2 1 0 7 6 5 4 3 2 1 0 Screw terminal label
B15 B14 B13 B12 B11 B10 B9 B8 B7 B6 B5 B4 B3 B2 B1 B0 Bit Position
0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 Binary Value
(2^15) (2^14) (2^13) (2^12) (2^11) (2^10) (2^9) (2^8) (2^7) (2^6) (2^5) (2^4) (2^3) (2^2) (2^1) (2^0) Weights
32768 16384 8192 4096 2048 1024 512 256 128 64 32 16 8 4 2 1 Equivalent decimal weight
1 1 0 0 0 0 0 0 1 0 0 0 1 0 0 0
7 6 5 4 3 2 1 0 7 6 5 4 3 2 1 0
1 1 0 0 0 0 0 0 1 0 0 0 1 0 0 0 Binary Value
32768 16384 8192 4096 2048 1024 512 256 128 64 32 16 8 4 2 1 Decimal weight
32768+16384+0+0 + 0 0 0 0 128+0+0+0 + 8+0+0+0 = 49288 (this is the NRf value in the command)
Therefore, the command to send is:
OUTP:DIG:WORD 49288,(@121)
Channel 21 of the Model 7706 in slot 1 (this command can only be sent to Channel 21)
NRf value of 49288 (specifies which terminals are 1 / 0)
16 bit
Digital
Output

Figure D-13
Typical digital output w/external power supply

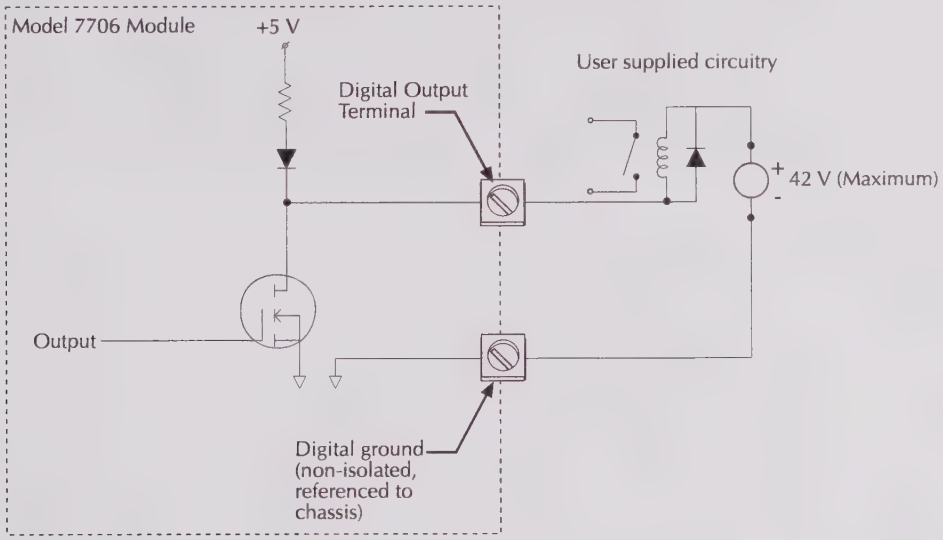
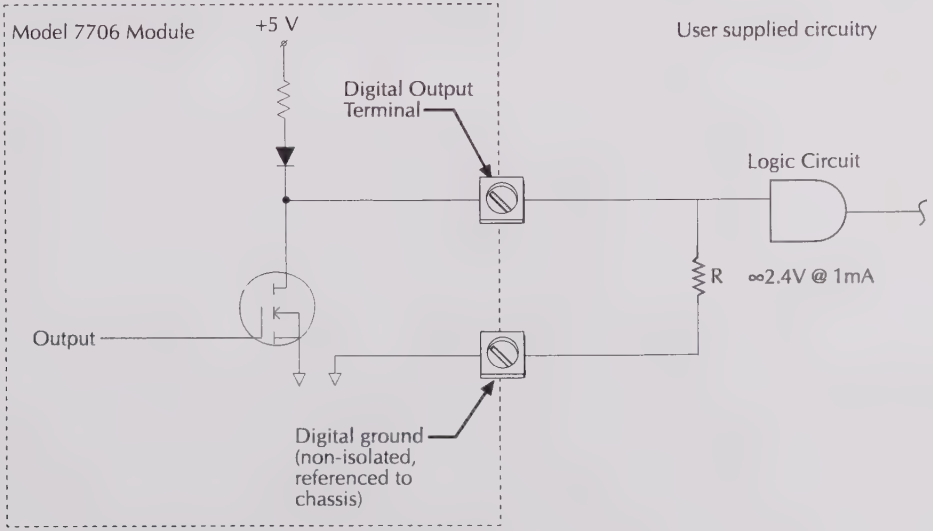


Figure D-14
Typical digital output (no external power supply)

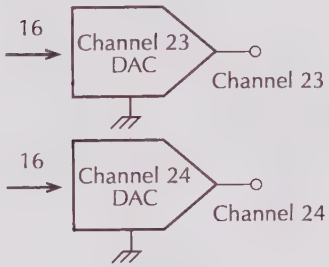


Analog outputs (channels 23–24)

CAUTION **Analog output current limit: 5mA (maximum).**

The Model 7706 contains two DAC (digital to analog converters). Use these analog outputs for tasks such as applying a voltage bias to DUTs or analog control. The two analog outputs of the Model 7706 are capable of providing voltages in the range of ± 12V. The analog outputs can be set from the front panel or over the bus. Figure D-15 shows a simplified schematic of the analog outputs.

Figure D-15
Analog output



In the following examples, the Model 7706 module is in slot one of the Model 2700.

Sample 1: Set analog output 1 (channel 23) to 10.0V

To set analog output 1 using the front panel: under the SHIFT->CARD menu, key in the decimal value (for this example, 10.0) for the menu item "AOUT1: +XX.XX", and press enter. To set channel 23 (analog output 1) over the bus, send the following command:

```
OUTP:VOLT 10.0,(@123)
```

NOTES *See "Front panel operation" for more information on menus and key location.*

Voltage may be set in 1mV steps (values are rounded to the nearest millivolt).

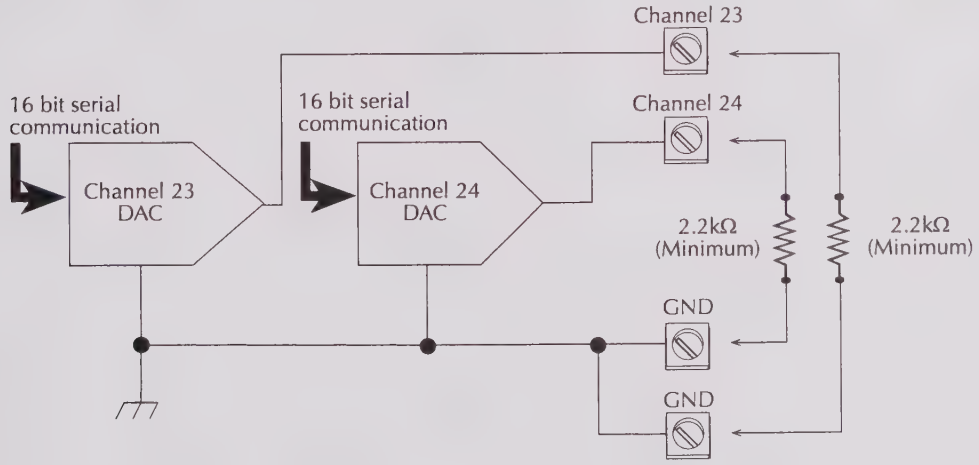
Sample 2: Set analog output 2 (channel 24) to -5.5V

To set analog output 2 using the front panel: under the SHIFT->CARD menu, key in the decimal value (for this example, -5.5) for the menu item "AOUT2: +XX.XX", and press enter. To set channel 24 (analog output 2) over the bus, send the following command:

```
OUTP:VOLT -5.5,(@124)
```

Note that each output is referenced to the chassis. Each output cannot "float" from each other. To operate with the analog output in specification as a calibrated voltage source, the minimum resistance load is 2.2kΩ (refer to Figure D-16).

Figure D-16
Sample analog connection schematic



Loading effects

Loading of the voltage source becomes a consideration for low resistance loads. As the source resistance increases, the error caused by loading increases. Figure D-17 shows the method used to determine the percent error due to loading where:

$\mathbf{V_s}$ is the programmed analog output of the Model 7706

$\mathbf{R_{Lead}}$ is the total lead resistance of the wiring and connections

$\mathbf{R_{Load}}$ is the resistance of the user's circuit

$\mathbf{V_M}$ is the measured voltage

The voltage actually measured by the meter is attenuated by the voltage divider action of R_S and R_I, and it can be calculated as follows:

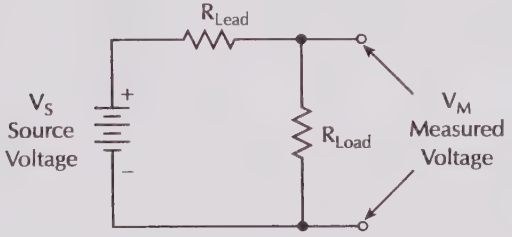
$$V_M = \frac{V_S \ R_{Load}}{R_{Load} + R_{Lead}}$$

This relationship can be modified to directly compute for percent error:

$$Percent\ Error = \frac{R_{Load}}{R_{Load} + R_{Lead}} \times 100$$

Using the above equation, to keep loading error within 0.1%, the resistance of the Model 7706 system must be at least 1/999th the value of load resistance.

Figure D-17
Loading effects



DAC output errors

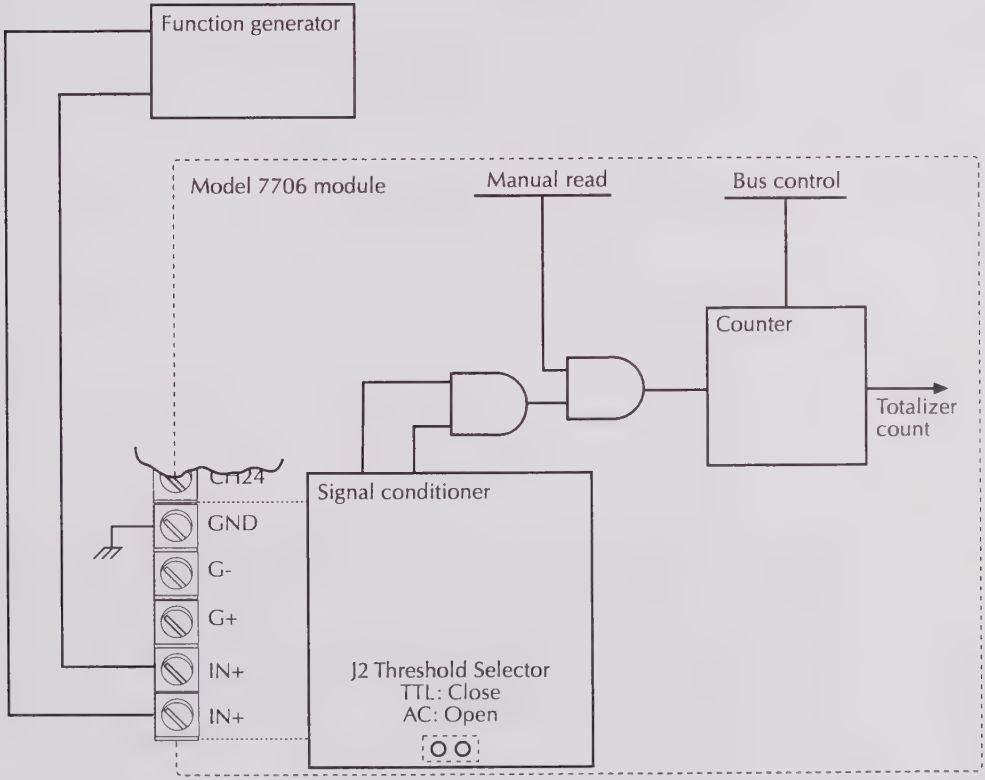
The DAC output is most accurate when the Model 7706 is operated in stable temperature conditions that are as close as possible to the environmental conditions used for calibration. Offset voltage drift over temperature is 1mV/°C. Also, the offset voltage value may change when changing from slot 1 to slot 2.

Totalizer

Use the Totalizer to count more than four billion on/off events (contact closures, revolutions, power cycles, etc.). The Totalizer can be accessed from the front panel or over the bus. Figure D-18 shows a simplified schematic of the Totalizer connected to a function generator.

NOTE *The Totalizer can count exactly up to 4,294,967,295 events (2^{32}-1). The count resets (sets its value to 0) when it reaches 2^{32}.*

Figure D-18
Totalizer



Threshold detection

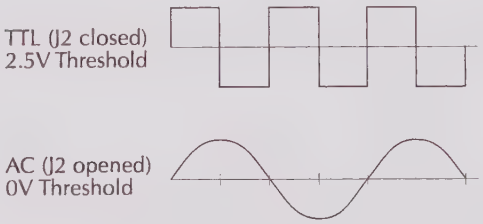
The Totalizer can count events at a rate of up to 100kHz. The count can be initiated manually or by configuring a scan. When counting, the Totalizer can:

- Reset to zero every time it is read
- Count on the rising or falling edge of the input signal
- Count AC or TTL signals
- Be governed by a gate signal

Either through a menu (Figure D-23) or over the bus (Table D-5), the Totalizer can be configured to read ("READ"), read and reset ("RRES"). It can also be configured to which edge of the signal is read (rising or falling).

The type of threshold detected by the Totalizer is set by the position of jumper J2 (see Figure D-3). Factory default setting for this jumper is closed (TTL). The TTL wave as well as the AC type wave form are shown in Figure D-19.

Figure D-19 AC and TTL waveforms

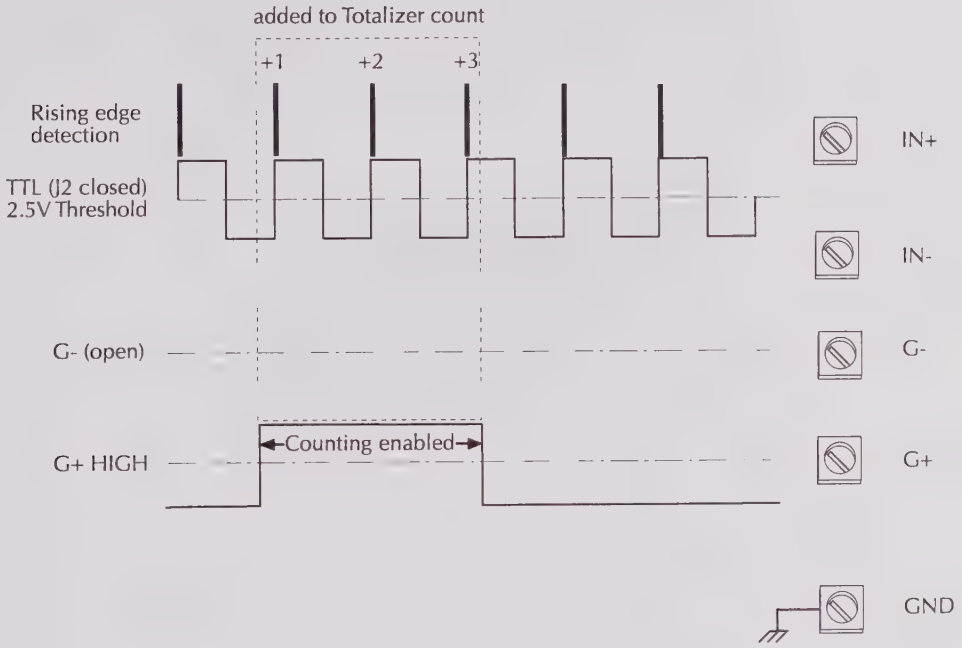


NOTES *The Totalizer counts when both terminals are either enabled or open.*

Threshold levels cannot be programmed or set.

Gating provides specific control over when the Totalizer readings are taken. A gate always is interpreted if no gating signal is present. To control counting through the G+ screw terminal, send a TTL high signal to enable counting and a TTL low signal to disable counting. To control counting through the G- screw terminal, send a TTL low signal to enable counting and a TTL high signal to disable counting. The Totalizer can be controlled from the G+ screw terminal, the G- screw terminal, or both (both G+ and G- screw terminals have to be enabled to count). Samples of Totalizer input with gating are contained in Figure D-20.

Figure D-20
Sample totalizer input with gating

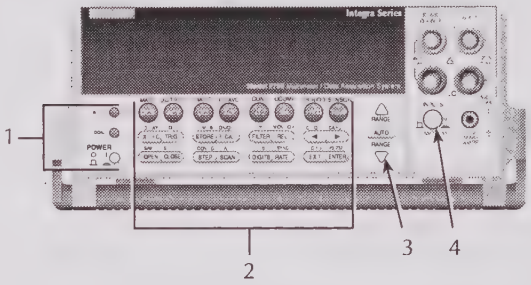


Viewing totalizer count

View the totalizer count by using the CLOSE key and entering the totalizer channel number (front panel). This opens all relays, switches the Model 2700 function to totalizer ("TOTALIZE"), and remembers the previous function. In this mode the TOTalize:TYPE setting is ignored (effectively 'READ").

The front panel of Model 2700 is shown in Figure D-21. When viewing the totalizer count, the Model 2700 keys function as contained in the list keyed to Figure D-21.

Figure D-21
Model 2700 front panel key operation (totalizer)



1 Special keys and power switch:

Normal operation.

2 Function and operation keys:

Top Row

Unshifted

DCV, ACV, DCI, ACI, Ω2, Ω4, FREQ, TEMP Blocked.

Shifted

RATIO,CH-AVG, CONT, OCOMP, PERIOD Blocked.

Middle Row

Unshifted

TRIG	Triggers the unit to read the current totalizer count.
◀ and ▶	Moves between totalizer channels (if more than one Model 7706 installed).
STORE, RECALL, FILTER, REL	Blocked.

Shifted

LIMITS	Sets the High Limit count for the Totalizer.
ON/OFF	Enables/disables limits.
MONITOR	Sets unit to monitor totalizer channel and turn monitor on. If monitor is already on, it will be turned off.
CARD	Enters the card specific menu.
DELAY, HOLD	Normal operation.
TYPE, CH-OFF	Blocked.

Bottom Row

Unshifted

OPEN, CLOSE	Normal operation.
EXIT	Clears the totalizer count to zero.
STEP, SCAN, DIGITS, RATE, ENTER	Blocked.

Shifted

SAVE, SETUP, CONFIG, TEST, GPIB, RS-232	Normal operation.
HALT, LSYNC	Blocked.

3 Range keys:

▲ and ▼	Normal operation.
AUTO	Blocked.

4 INPUTs switch:

Normal operation—the position of this switch does not affect Totalizer operation.

Adding totalizer to scan list (via front panel)

NOTE *Changing Totalizer settings ("READ" or "RRES") must be done outside of the scan-list configuration.*

Toggle the state of the totalizer channel in the scan list using the SHIFT->CH-OFF key. The TYPE and EDGE controls are set globally though the SHIFT->CARD menu key.

Adding to scan list via GPIB

The ROUT:SCAN command is used to add Totalizer to the scan list. When a card that supports totalizer is in the unit, the totalizer channel can only be used as a totalizer. Whenever it is added to the list, it will read the current count value. The TYPE and EDGE controls are set globally though the SENSe:TOTalize:EDGE and SENSe:TOTalize:TYPE commands.

Limits and analog trigger

The limit subsystem and analog scan triggering works the same for the TOTalize function as for any other Model 2700 function with the exception that only the UPPer limit is evaluated. The LOWer limit setting is ignored by the TOTalize function. The TOTalizer MUST be monitoring in order to initiate a scan based on a totalizer limit. When a scan is initiated by a TOTalizer count, and the Totalizer type is set to 'READ', the limit that initiated the scan is removed from the ROUTe:SCAN:TSOurce list so that the Model 2700 only runs through the scan list once. Otherwise, it would keep scanning since the TOTalizer count would remain above the upper limit until reset.

Totalizer channel monitor scan example

For this example, channel 25 of the Model 7706 is used to monitor the totalizer with the Model 7706 inserted into slot 1 of the Model 2700. This is an example of a four channel scan with channels 101–103 measuring DC voltage while, as previously mentioned, channel 125 monitors the totalizer. As programmed, when the totalizer reaches 100,000 counts, the scan is initiated.

Operation

A simplified model of scan operation is contained in Figure D-22. The procedure for front panel operation and equivalent programming commands for this simplified model is contained in Table D-1. For this example, there are two modes of operation: monitor and scan (see Figure D-22). While in monitor mode, continuous totalizer measurements are performed. The instrument remains in the monitor mode until it reaches the high limit (in this example, the high limit is set to 100,000 counts). When this limit is reached, the instrument changes over to scan mode (see Figure D-22). The instrument is configured to scan four channels: three DCV readings and the Totalizer channel (the buffer stores all four readings). After the fourth channel is measured, operation turns again to the monitor mode to again measure Totalizer.

NOTE *When scan is initiated by a TOTalizer count with the type set to READ, the limit that initiated the scan is removed from the ROUTe:SCAN:TSOurce list. This makes the unit run the scan list once. Otherwise, scanning would continue until reset as long as the TOTalizer count remains above the upper limit. If the type is set to RRES when a scan is initiated and after the Totalizer channel is scanned, it is reset to zero (0). If the Totalizer again counts past the high limit set, the unit will run the scan list again, reset the count to zero, and so on.*

Figure D-22
Monitor scan example

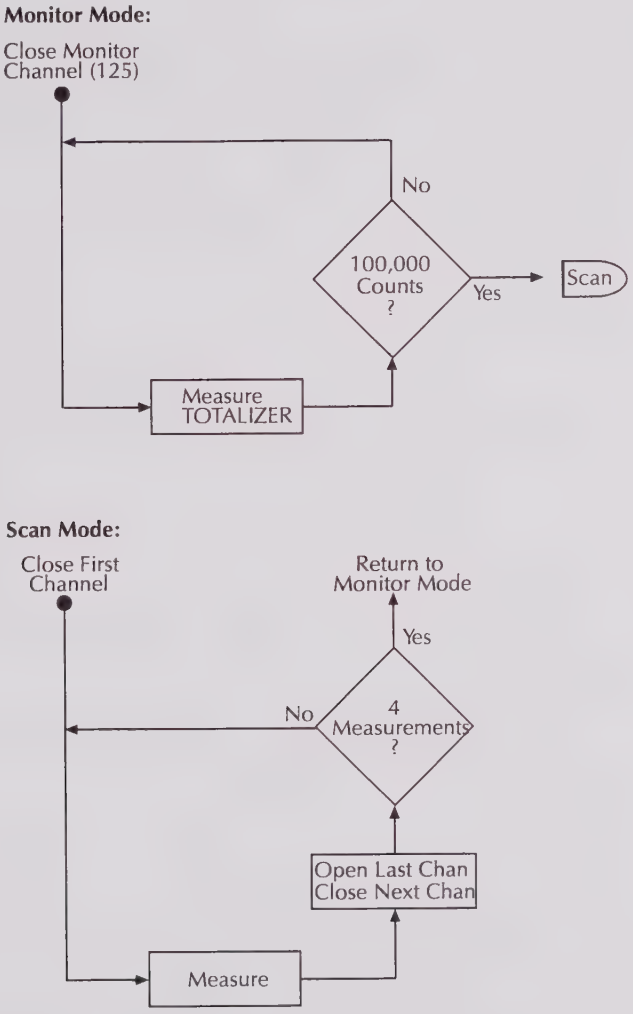


Table D-1
Monitor scan example (front panel and remote steps)

Step	Front panel operation	Remote programming
1	Restore defaults: Restore defaults (SHIFT SETUP > RESTORE: FACT).	*RST
2	For front panel operation, proceed to step 3. For remote programming, clear buffer and disable buffer auto clear:	TRAC:CLE
3	Configure advanced scan (SHIFT CONFIG > ADVANCED):	
a	Channel 101, 102, and 103: Select DCV function. Select 10V range. Set filter count to 20 (SHIFT TYPE > 020 RDGS). Enable filter (FILTER).	FUNC 'VOLT', (@101:103) VOLT:RANG 10,(@101:103) VOLT:AVER:COUN 20,(@101:103) VOLT:AVER:STAT ON,(@101:103)
b	Channel 104: Disable (off) channels 104-120 (SHIFT CH-OFF).	ROUT:SCAN (@101:103,125)
c	Channel 125: Enable Totalizer channel (SHIFT-CH OFF). Set and enable high limit 1: Set limit to 100000 (SHIFT LIMITS > HI1:+100.0000K). Set and enable high limit 2: Set limit to 1000000000 (SHIFT LIMITS > HI2:+1000000K). Enable (on) limit (SHIFT OFF/ON > LIMITS: ON).	CALC3:LIM1:UPP 1e5,(@125) CALC3:LIM1:STAT ON,(@125) ROUT:SCAN:TSO HLIM1
d	Disable immediate scan (IMM SCAN: N), and enable high limit 1 (HLIM1 SCAN:Y).	
e	Disable timer (TIMER? OFF).	
f	Set reading count to 4.	
4	For front panel operation, proceed to step 5. For remote programming, set the number of points in the monitor scan.	ROUT:MON:POIN 4
5	Select and enable monitor channel (SHIFT MONITOR > 125).	ROUT:MON (@125) ROUT:MON:STAT ON

Specifications

Full Model 7706 specifications are included in Appendix A of this manual.

Connection log

Make a copy of Table D-2 and affix it to the cover of the Model 7706. Use this to record connection information and channel descriptions as needed.

Table D-2
Connection log Model 7706

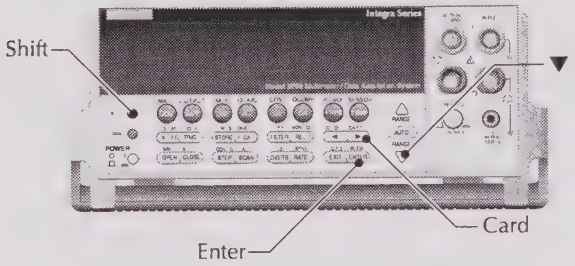
Channel		Color	Description
INPUT	H		
	L		
SENSE	H		
	L		
CH1	H		
	L		
CH2	H		
	L		
CH3	H		
	L		
CH4	H		
	L		
CH5	H		
	L		
CH6	H		
	L		
CH7	H		
	L		
CH8	H		
	L		
CH9	H		
	L		
CH10	H		
	L		
CH11	H		
	L		
CH12	H		
	L		
CH13	H		
	L		
CH14	H		
	L		
CH15	H		
	L		
CH16	H		
	L		
CH17	H		
	L		
CH18	H		
	L		
CH19	H		
	L		
CH20	H		
	L		
CH21	B0 B1 B2 B3 B4 B5 B6 B7 GND		
CH22	B0 B1 B2 B3 B4 B5 B6 B7 GND		
CH23	H		
	GND		
CH24	H		
	GND		
CH25	IN+ IN- G+ G-		

Front panel operation

Card specific menu

To open the card specific menu, press SHIFT->CARD (CARD is over the RIGHT arrow key). This menu contains all card-specific functions from the front panel. For example, the analog outputs of a 7706 card would be configured from here. A sample of accessing the card specific functions is contained in Figure D-23.

Figure D-23
Menu tree — Accessing card specific functions



Sequence	Key	Display
1	SHIFT-CARD	SLOT1: 7706
2	ENTER	AOUT1:+00.000V
3	▼	AOUT2:+00.000V
4	▼	DIGOUT1: 255
5	▼	DIGOUT2: 255
6	▼	TOT TYPE:(READ | RRES)
7	▼	TOT EDGE:(RISE | FALL)
8	▼	SWREV: A01
		Readings mode
9	▼	SLOT2: 7702
10	ENTER	Resumes normal readings since the Model 7702 does not have card-specific features that need to be addressed in this menu.

Bus commands

When issuing commands over the bus, keep the following channel usage in mind (Table D-3):

Table D-3
Channel description

Channels	Description
1-20	Voltage, resistance, temperature, frequency, period, etc., measurements.
21-22	Eight-bit digital outputs.
23-24	Sixteen-bit analog outputs.
25	Totalizer.
26	2/4 pole selection relay. Closing channel 26 makes a 4-pole measurement.
27	Sense terminals to backplane isolation.
28	Input terminals to backplane isolation.

Sending channel numbers

Express channel numbers as a three-digit number where the first digit is the slot number. For example, channel 1 on slot 1 would be channel 101, and channel 5 on slot 2 would be 205. The hundreds digit is the slot number, and the remaining digits denote the channel number on the card (see "Channel list parameter" located at the bottom of Table D-4).

OUTPut Subsystem

Commands to perform output operations are listed in Table D-4. Details on these commands follow the table.

NOTE *The output subsystem is specific to the Model 7706 module. It is only available if a Model 7706 is installed.*

Table D-4
Output subsystem commands

Command	Description	Default
:OUTPut	Set the output of a 7706 channel.	
:VOLTage <NRf>, <clist>	Forces the analog output of the given analog channel[s] to the desired values in volts from -12 to +12.	0.0
:VOLTage? <clist>	Query the present voltage for the analog output channel[s].	
:DIGital	Path to the digital commands.	
:BYTE <nrf>,<clist>	Force the digital output of the given channel[s] to the desired value ($0 < \times \leq 255$) in decimal format.	255
:BYTE? <clist>	Query the present bit pattern ($0 < \times \leq 255$) for the digital output channels.	
:WORD <nrf>,<clist>	Force the digital output of the given channel[s] to the desired value ($0 < \times \leq 65535$) in decimal format.	65535
:WORD? <clist>	Query the present bit pattern ($0 < \times \leq 65535$) for the digital output channels (returned in decimal format).	

Channel list parameter:
<clist> = (@SCH)
where: S = Mainframe slot number (1 or 2); CH = Switching module channel number (must be 2 digits);

Examples:
(@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

:OUTPut

As mentioned in Table D-3, channels 21 and 22 are eight-bit digital output channels, and channels 23 and 24 are analog output channels with a range of -12V to +12V. For individual digital channels, the range of values allowed is 0-255, and the outputs are set to the closest integer to the sent value. Analog outputs will accept values of -12 to +12. Attempting to use this command with an input channel generates error –221 settings conflict.

:VOLTage <nrf>,<clist> Force voltage
:VOLTage? <clist> Query voltage

Use to force (or query) the analog output of the given channel[s] to the desired value. Values are rounded to the nearest mV. (-12VDC < x < +12VDC).

:DIGital

:BYTE <nrf>,<clist> — Use to force the digital output of the given channel[s] to the desired value (0 < x < 255) in decimal format. Use this command to write to channel 21 or 22 individually. Bit 0 of each port is the LSB.

:BYTE? <clist> — Query the present bit pattern (0 < x < 255) for the digital output channels (returned in decimal format). Use this command to query channel 21 or 22 individually.

:WORD <nrf>,<clist> — Must write to the lower port (channel 21). Channel 21 bit 0 will be the LSB and channel 22 bit 7 will be the MSB.

:WORD? <clist> — Query the present bit pattern (0 < x < 65535) for the digital output channels (returned in decimal format). This command must be sent to channel 21.

SENSe[1] Subsystem

Commands to perform Model 7706 specific operations are listed in Table D-5.

Table D-5
Sense1 subsystem commands

Command	Description	Default
:SENSe[1]	Path to the :SENSe[1] commands.	
:TOTalize	Path to configure 7706 Totalizer.	
:TYPE < READ | RRESet >,<clist>	RRESet (read and reset) causes the totalizer count to be reset to zero every time it is read.	READ
:TYPE? <clist>	Query totalizer count readback type.	
:EDGE < RISing | FALLing >,<clist>	Set which edge of the input signal to count.	RIS
:EDGE? <clist>	Query trigger edge for the Totalizer.	
:DATA? <clist>	Query the current Totalizer count. This command will reset the count to 0 if TOT:TYPE is set to RRESet.	

Channel list parameter:
<clist> = (@SCH)
where: S = Mainframe slot number (1 or 2); CH = Switching module channel number (must be 2 digits);

Examples:
(@101) = Slot 1, Channel 1
(@101, 203) = Slot 1, Channel 1 and Slot 2, Channel 3
(@101:110) = Slot 1, Channels 1 through 10

Unsupported SCPI commands

NOTE *The display will indicate which cards are installed immediately after showing the firmware revision at power-up.*

The ROUT:SCAN:NVOLatile command is not supported for Model 7706 module operation. Attempts to set ROUT:SCAN:NVOL ON with a 7706 card present in either slot will generate Error -221 Settings Conflict.

Verification

Use the procedures contained in this section to verify the analog outputs or the totalizer.

Analog outputs

WARNING **The information contained in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so.**

Use the following steps to verify the Model 7706 analog output channels.

NOTE *After correctly wiring the Model 7706, installing it in the Model 2700, and turning the power on (step 5 in the following procedure), the unit is required to warm-up for two hours before proceeding.*

1. Connect CH23 H and L outputs to CH1 H and L input terminals (respectively).
2. Connect CH24 H and L outputs to CH2 H and L input terminals (respectively).
3. Close and lock the Model 7706 cover.
4. Install the Model 7706 in slot 1 of the Model 2700.
5. Turn on the Model 2700.
6. Allow unit to warm up for two hours before proceeding.
7. Set the front panel INPUTS switch to the REAR position.
8. Set the Model 2700 to the 10V range
   a. Select the DC volts function by pressing the DCV key.
   b. Select the 10V range.
9. Close channel 1:
   a. Press the CLOSE key.
   b. Key in 101.
10. Set analog output 1 to +10V:
    a. Open the SHIFT-CARD menu (press SHIFT-CARD).
    b. Key in analog output for AOUT1:+10.000V.
11. Verify analog output reading is within stated limits (see Table D-6).

12. Set analog output 1 to -10V:
    a. Open the SHIFT-CARD menu (press SHIFT-CARD).
    b. Key in analog output for AOUT1:-10.000V.
13. Verify analog output reading is within stated limits.
14. Close channel 2:
    a. Press the CLOSE key.
    b. Key in 102.
15. Set analog output 2 to +10V:
    a. Open the SHIFT-CARD menu (press SHIFT-CARD).
    b. Key in analog output for AOUT2:+10.000V.
16. Verify analog output reading is within stated limits.
17. Set analog output 2 to -10V:
    a. Open the SHIFT-CARD menu (press SHIFT-CARD).
    b. Key in analog output for AOUT2:-10.000V.
18. Verify analog output reading is within stated limits.
19. Open channel 2:
    a. Press the OPEN key.

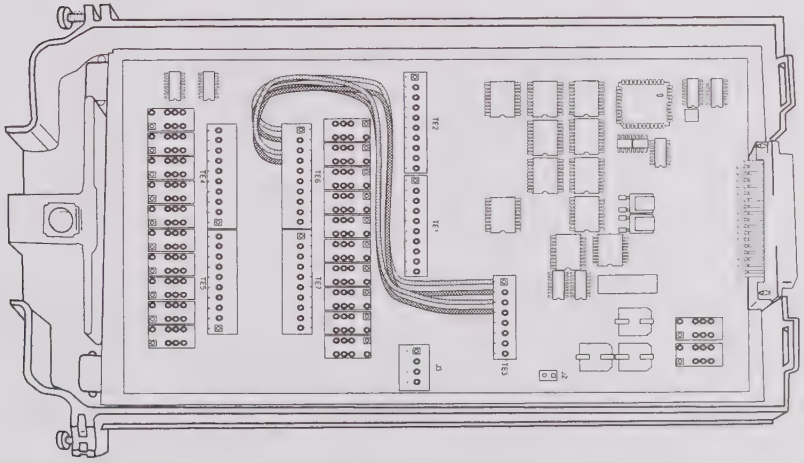


Figure D-24
Verification—analog connections

Table D-6
Analog output limits

Source DC Voltage	Reading limits (1 year, 18° to 28°C)
+10V	+9.966 to +10.034V 0.15% of reading + 19mV
-10V	-10.034 to -9.966V

Totalizer

WARNING **The information contained in this section is intended only for qualified service personnel. Do not attempt these procedures unless you are qualified to do so.**

NOTE *Correctly wire and install the Model 7706 in the Model 2700 before turning on the Model 2700.*

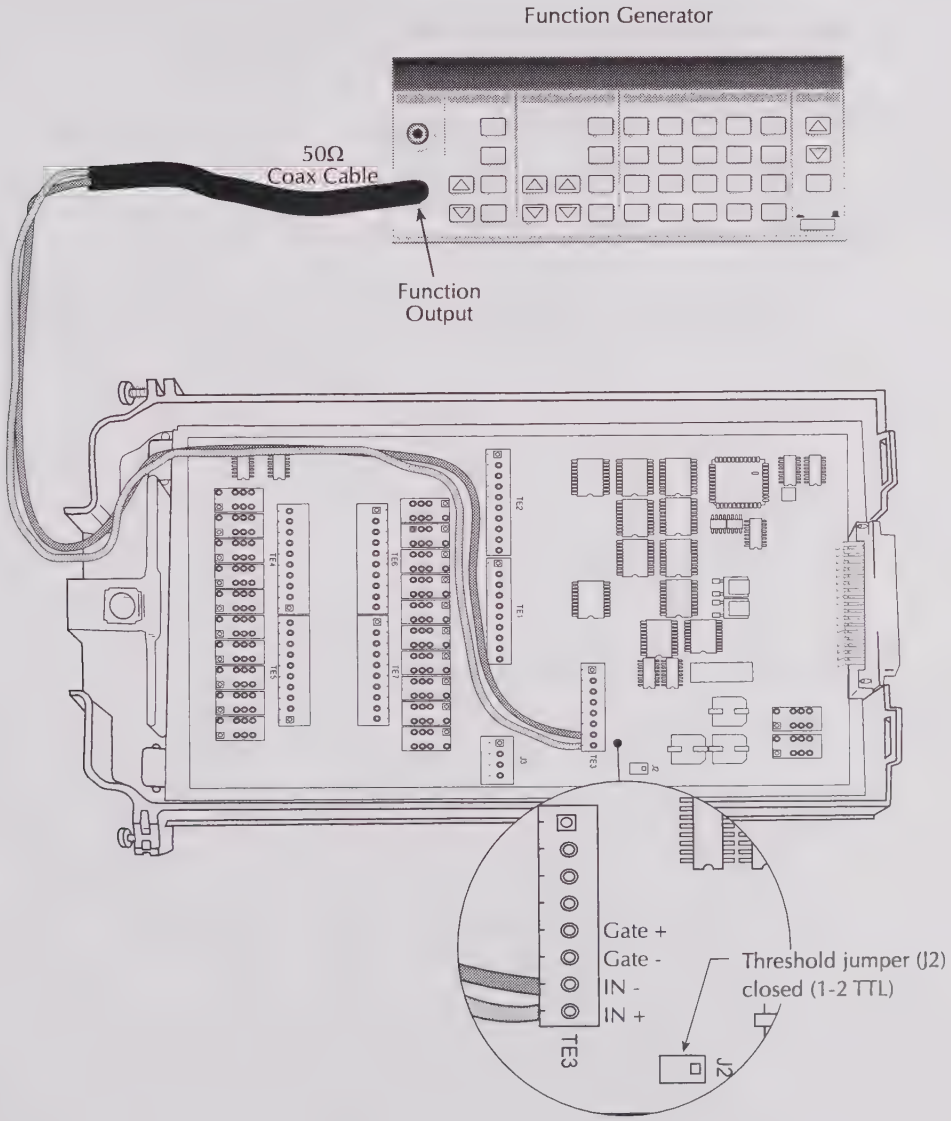
Use the following steps to verify the Model 7706 Totalizer function.

1. Connect the function generator to the Model 7706 Totalizer IN+ and IN- terminals (see Figure D-25).
2. Make sure to leave gate inputs (G+ and G-) open (gate always).
3. Set the threshold jumper to the TTL position (J2 closed).
4. Close and lock the Model 7706 cover.

NOTE *Make sure the Model 2700 is off before installing the Model 7706.*

5. Install the Model 7706 in slot 1 of the Model 2700.
6. Turn on the Model 2700.
7. Set the function generator to:
   - Burst mode
   - Burst cycle count of 50,000
   - Manual trigger source
   - Output: 100kHz
   - 0–5V square wave (50% duty cycle)
8. Close CH25:
   a. Press the CLOSE key.
   b. Key in 125.
9. Check Totalizer count — if count is not zero, press EXIT key to clear count.
10. Verify that each time the function generator is triggered to output a burst, the Totalizer count increases by 50,000.
11. Open CH25:
    a. Press the OPEN key.

Figure D-25
Verification—totalizer connections



Calibration

The following procedures calibrate the temperature sensors on the Model 7706 plug-in module as well as the analog outputs.

Recommended test equipment

In order to calibrate the Model 7706, you will need equipment summarized in Table D-7.

Extender board connections

The Model 7706 being calibrated should be connected to the 7798-250B Calibration/ Extender Board, and the extender board must be installed in scanner Slot #1. Note that the module being calibrated will be external to the Model 2700 to avoid card heating during calibration.

Table D-7
Recommended calibration equipment

Description
Digital thermometer: 18° to 28°C, ±0.1°C
Keithley 7798-250B Calibration Extender Board

Front panel Model 7706 temperature calibration

NOTE *Before calibrating the temperature on the Model 7706, make sure that power has been removed from the card for at least two hours to allow card circuitry to cool down. After turning on the power during the calibration procedure, complete the procedure as quickly as possible to minimize card heating that could affect calibration accuracy. Allow the Model 2700 to warm up for at least two hours.*

1. Connect the Model 7706 to the 7798-250B Calibration Extender Board.
2. With the power off, install the Model 7706/7798 combination in Slot 1, and select the rear inputs with the INPUTS switch.
3. Press in and hold the Model 2700 OPEN key while turning on the power.
4. Allow five minutes for thermal equilibrium.
5. Accurately measure and record the cold temperature of the Model 7706 card surface at the center of the card.
6. Press SHIFT then TEST, then display TEST:CALIB with the up or down range key. Press ENTER, select RUN, then enter the appropriate calibration code (default: 002700).

7. Using the up or down range key, select CARD at the CAL:RUN prompt, then press ENTER.
8. Using the up or down range key, select TEMP, then press ENTER.
9. Set the display value to the cold junction calibration temperature (°C) measured in Step 4, then press ENTER to complete Model 7706 temperature calibration.

Remote Model 7706 temperature calibration

1. Connect the Model 7706 to the 7798-250B Calibration/Extender Board.
2. With the power off, install the Model 7706/7798 combination in Slot 1, and select the rear inputs with the INPUTS switch.
3. Press in and hold the Model 2700 OPEN key while turning on the power.
4. Allow five minutes for thermal equilibrium.
5. Accurately measure and record the cold temperature of the Model 7706 card surface at the center of the card.
6. Turn on the Model 2700 power.
7. Unlock calibration by sending:
   ```
   :DIAG:KEIT:CAL:UNLOCK
   ```
8. Enable calibration by sending the :CODE command. For example, the default command is:
   ```
   :CAL:PROT:CODE 'KI002700'
   ```
9. Initiate calibration by sending the following command:
   ```
   :CAL:PROT:CARD1:INIT
   ```
10. Calibrate temperature on the Model 7706 with the following command:
    ```
    :CAL:PROT:CARD1:STEP0 <temp>
    ```
    Here <temp> is the cold calibration temperature measured in Step 4.
11. Send the following commands to save calibration, and lock out calibration:
    ```
    :CAL:PROT:CARD1:SAVE
    :CAL:PROT:CARD1:LOCK
    ```

Front Panel Model 7706 analog output (DAC) calibration

1. Connect the Model 7706 CH23 and 24 to CH1 and 2 (use the same connection setup as in Figure D-24):
   - Connect CH23 H and L terminals to CH1 H and L terminals (H to H; L to L).
   - Connect CH24 H and L terminals to CH2 H and L terminals (H to H; L to L).
2. With the power off, install the Model 7706 in Slot 1, and select the rear inputs with the INPUTS switch.
3. Press in and hold the Model 2700 OPEN key while turning on the power.
4. Allow unit to warm up for two hours before proceeding.
5. Press the SHIFT key and then the TEST key.
6. Select TEST:CALIB using the up or down range keys.

7. Press the ENTER key, select RUN, and enter the appropriate calibration code (default: 002700).
8. Using the up or down range key, select CARD at the CAL:RUN prompt, then press ENTER.
9. Using the up or down range key, select DAC at the next CARD prompt, then press ENTER to complete Model 7706 DAC calibration.

Remote Model 7706 analog output (DAC) calibration

1. Connect the Model 7706 CH23 and 24 to CH1 and 2 (use the same connection setup as in Figure D-24):
   - Connect CH23 H and L terminals to CH1 H and L terminals (H to H; L to L).
   - Connect CH24 H and L terminals to CH2 H and L terminals (H to H; L to L).
2. With the power off, install the Model 7706 in Slot 1, and select the rear inputs with the INPUTS switch.
3. Turn on the Model 2700 power.
4. Allow unit to warm up for two hours before proceeding.
5. Unlock calibration by sending:
   ```
   :DIAG:KEIT:CAL:UNLOCK
   ```
6. Enable calibration by sending the :CODE command. For example, the default command is:
   ```
   :CAL:PROT:CODE 'KI002700'
   ```
7. Initiate calibration by sending the following command:
   ```
   :CAL:PROT:CARD1:INIT
   ```
8. Calibrate the Model 7706 analog output with the following command:
   ```
   :CAL:PROT:CARD1:DAC:STEP0
   ```
9. Send the following commands to save calibration, and lock out calibration:
   ```
   :CAL:PROT:CARD1:SAVE
   :CAL:PROT:CARD1:LOCK
   ```

Calibration commands

Table D-8 summarizes calibration commands for the Model 7706 plug-in module. Note that CARD1 commands calibrate the card in Slot 1, while CARD2 commands request calibration count and date information from a card in Slot 2.

NOTE *The 7706 must be installed in Slot 1 through a Model 7798 extender card to perform temperature calibration. See "Extender board connections."*

Table D-8
Model 7706 calibration commands

Command	Description
:CALibration	Calibration root command.
:PROTected	All commands in this subsystem are protected by the calibration lock (except queries and :CODE).
:CODE '<up to 8 char. string>'	Send calibration code. (Default KI002700.)
:CARD1	Path to card in slot 1.
:INITiate	Initiate card calibration.
:COUNt?	Request number of times card had been calibrated.
:RCOunt	Reset card calibration count to 0.
:DATE?	Request card cal. date.
:SAVE	Save cal constants to card EEPROM.
:LOCK	Lock out calibration.
:LOCK?	Request cal lock state. (0 = locked, 1 = unlocked.)
:STEP0 <NRf>	Temperature sensor cold calibration (<NRf> = temperature, °C).
:DAC	Path to analog output calibration.
:STEP0 <NRf>	Analog output DAC calibration.
:CARD2	Path to card in slot 2.
:COUNt?	Request number of times card has been calibrated.
:DATE?	Request card calibration date.
:DIAGnostic	Diagnostic root.
:KEIThley	Keithley path.
:CALibration	Calibration path.
:UNLOCK	Unlock command.

:CODE

(:CALibration:PROTected:CODE)

NOTES *The :CODE command should be sent only once before performing calibration. Do not send :CODE before each calibration step.*

The code parameter must be enclosed in single quotes.

Purpose To program the calibration code or password so that you can perform the Model 7706 calibration procedures.

Format
```
:cal:prot:code '<char_string>'
```

Parameters Up to a 8-character string including letters and numbers.

Description The :CODE command enables the Model 2700 calibration procedures when performing these procedures over the bus. This command must be sent to the unit before sending any other Model 7706 calibration command. The default calibration code is KI002700.

Example
```
:CAL:PROT:CODE 'KI002700'
```
Send default code of KI002700.

:COUNt?

(:CALibration:PROTected:CARD1:COUNt?)
(:CALibration:PROTected:CARD2:COUNt?)

Purpose To determine how many times a Model 7706 has been calibrated.

Format
```
:CAL:PROT:CARD1:COUN?
:cal:prot:card2:coun?
```

Response <n> Calibration count.

Description The :CARD1:COUNt? and :CARD2:COUNt? commands allow you to determine how many times a Model 7706 in Slot 1 and Slot 2 respectively has been calibrated.

NOTE *Use the :COUNt? command to help you monitor for unauthorized calibration procedures.*

Example
```
:CAL:PROT:CARD1:COUN?
```
Request card 1 calibration count.

:DATE?

(:CALibration:PROTected:CARD1:DATE?)
(:CALibration:PROTected:CARD2:DATE?)

Purpose To request the Model 7706 calibration date.

Format
```
:CAL:PROT:CARD1:DATE?
:cal:prot:card2:date?
```

Response <year>, <month>, <day>

Description The :CARD1:DATE? and :CARD2:DATE? queries allow you to read back the calibration date from a Model 7706 in Slot 1 and Slot 2 respectively.

NOTE *The card calibration date is automatically set to the Model 2700 real time clock date when the card is calibrated.*

Example
```
:CAL:PROT:CARD1:DATE?
```
Request card 1 cal date.

:INIT

(:CALibration:PROTected:CARD1:INITiate)

Purpose To initiate Model 7706 calibration procedures.

Format
```
:CAL:PROT:CARD1:INIT
```

Parameters None

Description The :INIT command enables Model 7706 calibration when performing these procedures over the bus. This command must be sent to the unit after sending the :CODE command, but before performing Model 7706 calibration.

Example
```
:CAL:PROT:CARD1:INIT
```
Initiate 7706 calibration.

:LOCK

(:CALibration:PROTected:CARD1:LOCK)

Purpose To lock out Model 7706 calibration.

Format
```
:CAL:PROT:CARD1:LOCK
```

Parameters None

Description The :LOCK command allows you to lock out Model 7706 calibration after completing the procedure. Thus, :LOCK performs the opposite of enabling calibration with the :CODE command.

Example
```
:CAL:PROT:CARD1:LOCK
```
Lock out card 1 calibration.

:LOCK?

(:CALibration:PROTected:CARD1:LOCK?)

Purpose To read Model 7706 calibration lock status.

Format `:CAL:PROT:CARD1:LOCK?`

Response 0 Calibration locked.
1 Calibration unlocked.

Description The :LOCK? query requests status from the Model 2700 on Model 7706 calibration locked/unlocked state. Calibration must be enabled sending the :CODE command before calibration can be performed.

Example `:CAL:PROT:CARD1:LOCK?` Request card 1 cal lock state.

:SAVE

(:CALibration:PROTected:CARD1:SAVE)

Purpose To save calibration constants in card EEROM after the calibration procedure.

Format `:CAL:PROT:CARD1:SAVE`

Parameters None

Description The :SAVE command stores calculated calibration constants derived during Model 7706 calibration in card EEROM. (EEROM is non-volatile memory.) Calibration constants will be retained indefinitely once saved.Generally, :SAVE is sent after all other calibration steps (except for :LOCK).

NOTE *Card calibration will be only temporary unless the :SAVE command is sent to permanently store calibration constants.*

Example `:CAL:PROT:CARD1:SAVE` Save card calibration constants.

:STEP0

(:CALibration:PROTected:CARD1:STEP0)

Purpose To perform Model 7706 temperature calibration.

Format `:CAL:PROT:CARD1:STEP0 <TEMP>`

Parameters <temp> = Cold calibration temperature (°C)

Description :STEP0 performs temperature sensor calibration of the Model 7706. The card must be allowed to cool down to ambient temperature before calibration, and the cold temperature of the card must be measured and sent as the <temp> parameter during calibration.

NOTE *Before calibrating the temperature for the Model 7706, make sure that power has been removed from the card for at least two hours to allow card circuitry to cool down. After turning on the power during the calibration procedure, complete the procedure as quickly as possible to minimize card heating that could affect calibration accuracy.*

Example `:CAL:PROT:CARD1:STEP0 23` Perform 7706 temperature calibration with card at a temperature of 23°C (measured with an external probe).

:DAC

:STEP0

(:CALibration:PROTected:CARD1:DAC:STEP0)

Purpose To perform Model 7706 analog output (DAC) calibration.

Format `:CAL:PROT:CARD1:DAC:STEP0`

Parameters none

Description :STEP0 performs analog output calibration of the Model 7706. The card must be allowed to warm-up inside the powered-up unit for two hours before calibration. In this step, CH23 (analog output 1) must be connected to CH1, and CH24 (analog output 2) must be connected to CH2.

Example `:CAL:PROT:CARD1:DAC:STEP0` Perform 7706 DAC calibration.

(:CALibration:PROTected:CARD1:STEP0)

Purpose To perform Model 7706 temperature calibration.

Format `:CAL:PROT:CARD1:STEP0 <TEMP>`

Parameters <temp> = Cold calibration temperature (°C)

Description :STEP0 performs temperature sensor calibration of the Model 7706. The card must be allowed to cool down to ambient temperature before calibration, and the cold temperature of the card must be measured and sent as the <temp> parameter during calibration.

NOTE *Before calibrating the temperature on the Model 7706, make sure that power has been removed from the card for at least two hours to allow card circuitry to cool down. After turning on the power during the calibration procedure, complete the procedure as quickly as possible to minimize card heating that could affect calibration accuracy.*

Example `:CAL:PROT:CARD1:STEP0 23` Perform 7706 calibration.

Remote error reporting

Methods to detect and determine the nature of calibration errors are discussed below.

Error summary

Table D-9 summarizes Model 2700 calibration errors.

Error queue

As with other Model 2700 errors, any calibration error will be reported in the bus error queue. You can read this queue by using the :SYST:ERR? query. The Model 2700 will respond with the appropriate error message, as summarized in Table D-9.

Status byte EAV (Error Available) bit

Whenever an error is available in the error queue, the EAV (Error Available) bit (bit 2) of the status byte will be set. Use the *STB? query or serial polling to obtain the status byte, then test bit 2 to see if it is set. If the EAV bit is set, an error has occurred, and you can use the :SYST:ERR? query to read the error and at the same time clear the EAV bit in the status byte.

Table D-9
Calibration error summary

Error number and description	Error number and description
+400, "10 vdc zero error"	+455, "100m vac full scale error"
+401, "100 vdc zero error"	+456, "1 vac zero error"
+402, "10 vdc full scale error"	+457, "1 vac full scale error"
+403, "-10 vdc full scale error"	+458, "1 vac noise error"
+404, "100 vdc full scale error"	+459, "10 vac zero error"
+405, "-100 vdc full scale error"	+460, "10 vac full scale error"
+406, "1k 2-w zero error"	+461, "10 vac noise error"
+407, "10k 2-w zero error"	+462, "100 vac zero error"
+408, "100k 2-w zero error"	+463, "100 vac full scale error"
+409, "10M 2-w zero error"	+464, "750 vac zero error"
+410, "10M 2-w full scale error"	+465, "750 vac full scale error"
+411, "10M 2-w open error"	+466, "750 vac noise error"
+412, "1k 4-w zero error"	+467, "Post filter offset error"
+413, "10k 4-w zero error"	+468, "1 aac zero error"
+414, "100k 4-w zero error"	+469, "1 aac full scale error"
+415, "10M 4-w sense lo zero error"	+470, "3 aac zero error"
+416, "1k 4-w full scale error"	+471, "3 aac full scale error"
+417, "10k 4-w full scale error"	+472, "Input time constant error"
+418, "100k 4-w full scale error"	+473, "Frequency gain error"
+419, "1M 4-w full scale error"	+474, "1K Ohm Ioff Ocomp FS error"
+420, "10M 4-w full scale error"	+475, "10K Ohm Ioff Ocomp FS error"
+421, "10m adc zero error"	+476, "Temperature Cold Cal error"
+422, "100m adc zero error"	+477, "Analog output zero error"
+423, "10m adc full scale error"	+478, "Analog output pos. gain error"
+424, "100m adc full scale error"	+479, "Analog output neg. gain error"
+425, "1 adc full scale error"	+500, "Calibration data invalid"
+438, "Date of calibration not set"	+513, "AC calibration data lost"
+439, "Next date of calibration not set"	+514, "DC calibration data lost"
+450, "100m vac dac error"	+515, "Calibration dates lost"
+451, "1 vac dac error"	+518, "Card calibration data lost"
+452, "10 vac dac error"	+519, "Card calibration dates lost"
+453, "100 vac dac error"	+610, "Questionable calibration"
+454, "100m vac zero error"	

Generating an SRQ on error

To program the instrument to generate an IEEE-488 bus SRQ when an error occurs, send the following command: *SRE 4. This command will enable SRQ when the EAV bit is set. You can then read the status byte and error queue as outlined above to check for errors, and to determine the exact nature of the error.

Detecting calibration step completion

When sending remote calibration commands, you must wait until the instrument completes the current operation before sending a command. You can use either *OPC? or *OPC to help determine when each calibration step is completed.

Using the *OPC? query

With the *OPC? (operation complete) query, the instrument will place an ASCII 1 in the output queue when it has completed each step. To determine when the OPC response is ready, do the following:

1. Repeatedly test the MAV (Message Available) bit (bit 4) in the status byte and wait until it is set. (You can request the status byte by using the *STB? query or by serial polling.)
2. When MAV is set, a message is available in the output queue and you can read the output queue and test for an ASCII 1.
3. After reading the output queue, repeatedly test MAV again until it clears. At this point, the calibration step is completed.

Using the *OPC command

The *OPC (operation complete) command can also be used to detect the completion of each calibration step. To use *OPC to detect the end of each calibration step, you must do the following:

1. Enable operation complete by sending *ESE 1. This command sets the OPC (operation complete bit) in the standard event enable register, allowing operation complete status from the standard event status register to set the ESB (Event Summary Bit) in the status byte when operation complete is detected.
2. Send the *OPC command immediately following each calibration command. For example:

   ```
   :CAL:PROT:DC:STEP1;*OPC
   ```

   Note that you must include the semicolon (;) to separate the two commands, and that the *OPC command must appear on the same line as the calibration command.

3. After sending a calibration command, repeatedly test the ESB (Event Summary Bit) (bit 5) in the status byte until it is set. (Use either the *STB? query or serial polling to request the status byte.)
4. Once operation complete has been detected, clear OPC status using one of two methods: (1) Use the *ESR? query, then read the response to clear the standard event status register, or (2) send the *CLS command to clear the status registers. Note that sending *CLS will also clear the error queue and operation complete status.

Generating an SRQ on calibration complete

An IEEE-488 bus SRQ (service request) can be used to detect operation complete instead of repeatedly polling the Model 2700. To use this method, send both *ESE 1 and *SRE 32 to the instrument, then include the *OPC command at the end of each calibration command line, as covered above. Refer to your controller's documentation for information on detecting and servicing SRQs.

Replaceable parts

Introduction

This section contains replacement parts information and component layout drawings for the Model 7706.

Parts lists

Both electrical and mechanical parts for the Model 2700 are listed in several tables on the following pages.

Ordering information

To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory (see inside front cover for addresses). When ordering parts, be sure to include the following information:

- Card model number (Model 7706 module)
- Card serial number
- Part description
- Component designation (if applicable)
- Keithley part number

Factory service

If the instrument is to be returned to Keithley Instruments for repair, perform the following:

- Call the Repair Department at 1-888-KEITHLEY for a Return Material Authorization (RMA) number.
- Complete the service form at the back of this manual, and include it with the instrument.
- Carefully pack the instrument in the original packing carton.
- Write ATTENTION REPAIR DEPARTMENT and the RMA number on the shipping label.

Component layout

A component layout for the Model 7706 circuit board is provided on the pages following the parts list table, Table D-10.

Table D-10
Model 7706 parts list

Circuit Designation	Description	Keithley Part No.
C1,C2,C3,C4,C6	CAP, 1000PF, 10%, 50V, MONO CERAMIC	C-452-1000P
C13	CAP, 47P, 5%, 100V, CERAMIC	C-465-47P
C14	CAP, 47P, 5%, 100V, CERAMIC	C-465-47P
C16	CAP, 22U, 20%, 25V, TANTALUM	C-535-22
C17,C22,C23	CAP, 0.47U, 20%, 25V	C-520-.47
C18,C19,C20,C21,C28,C29	CAP, 100P, 10%, 100V, CERAMIC	C-451-100P
C39,C40	CAP, 47UF, 20%, 20V, TANTALUM	C-575-47
C41	CAP, 10UF, 20%, 25V, TANTALUM	C-440-10
C42,C43,C44,C45	CAP, 1000P, 10%, 100V, CERAMIC	C-451-1000P
C47	CAP, 1000pF, 20%, 50V, CERAMIC	C-418-1000P
C48	CAP, 0.01uF, 20%, 50V, CERAMIC	C-418-.01
C7-C9,C10-12,C24-C27,C30-C35, 38,46,49-53	CAP, 0.1UF, 20%, 50V, CERAMIC	C-418-.1
CR2-6,25,28,42,44,46,48,43,45,47, 49,50	DIODE, DUAL SWITCHING, BAV99L	RF-82
CR26,CR27	DIODE, DUAL HSM-2822T31	RF-95
CR29,CR30,CR40,CR41	DIODE, DUAL HIGH SPEED	RF-147
CR31,32,34,36,38,1,33,35,37,39	DIODE, DUAL SWITCHING, BAV99L	RF-82
CR51-CR54	DIODE, DUAL SWITCHING, BAV99L	RF-82
CR7-CR22	DIODE, DUAL COMMON ANODE BAW56LT2	RF-98

Table D-10 (Continued)
Model 7706 parts list

Circuit Designation	Description	Keithley Part No.
J1	CONN, RT ANGLE DUAL ROW RECEPT	CS-1065-1
J2	CONN, BERG	CS-339
K1-K20,K23	SINGLE COIL LATCHING	RL-244
K21,K22	RELAY, NON LATCHING	RL-243
L1,L2,L3,L4	FERRITE CHIP, 600 OHM, BLM32A07	CH-62
Q1,Q2,Q3,Q4,Q53,Q54,Q56,Q58	TRANS, NPN SILICON	TG-389
Q25,27,29,31,33,35,37,39,41,43,45, 47,49	TRANS, PNP SILICON	TG-388
Q26,28,30,32,34,36,38,40,42,44,46, 48,50	TRANS, NPN SILICON	TG-389
Q5,Q6	P CHANNEL TMOSFET	TG-392
Q51	TRANS, PNP SILICON	TG-388
Q52	TRANS, NPN SILICON	TG-389
Q55,Q57	TRANS, PNP SILICON	TG-388
Q9-Q24	TRANS, N-MEGAFET, RFD14N05LSM	TG-267
R122,R126,R30	RES ARRAY, 4×10K, 5%, 0.125W	TF-276-10K
R13,R14,R17,R18	RES, 499K, 1%, 125MW, METAL FILM	R-391-499K
R19,R21	RES, 332, 10%, 125MW, METAL FILM	R-391-332
R1-R12,R15,R16	RES, 13K, 1%, 125MW, METAL FILM	R-391-13K
R20,R22	RES, 2K, 1%, 125mW, METAL FILM	R-391-2K
R23	RES, 28.7K, 1%, 0.125W, METAL FILM	R-391-28.7K
R24,R25	RES, 4.75K, 1%, 125mW, METAL FILM	R-391-4.75K
R26	RES, 49.9K, 1%, 125MW, METAL FILM	R-391-49.9K
R27	RES, 4.99K, 1%, 125mW, METAL FILM	R-391-4.99K
R28,32-34,39,59-63,73,74,76,77	RES, 220, 5%, 125MW, METAL FILM	R-375-220
R29,R86,R87	RES ARRAY, 4×4.3K, 5%, 0.125W	TF-276-4.3K
R31,R38,R40	RES, 475, 1%, 100MW, THICK FILM	R-418-475
R36,R37,R41-R46,R75,R85,R35	RES, 1K, 5%, 125MW, METAL FILM	R-375-1K
R51,R52,R55,R56	RES, ARRAY 4×100K, 5%, 0.125W	TF-276-100K
R53,54,57,58,94-97,100-102	RES ARRAY 4×10K, 5%, 0.125W	TF-276-10K
R64,R65,R66,R67	RES, 12.4, 10%, 100MW, THICK FILM	R-418-12.4K
R68,R69	RES, 40.2K, 1%, 100MW, THICK FILM	R-418-40.2K
R70,R71	RES, 54.9, 1%, 100MW, THICK FILM	R-418-54.9

Table D-10 (Continued)
Model 7706 parts list

Circuit Designation	Description	Keithley Part No.
R78,R79,R80,R81	RES, ARRAY 4×1K 5%, 0.125W	TF-276-1K
R82,R83	RES, 10K, 5%, 125MW, METAL FILM	R-375-10K
R84	RES, 100K, 5%, 125mW, METAL FILM	R-375-100K
RV1,RV2,RV3,RV4	BIDIRECTIONAL TRANSIENT VOLT SUPPRESSOR	VR-8
SO33	SOCKET	SO-143-44
TE1,TE2	CONN, FEMALE 12-PIN	TE-118-12
TE3,TE4,TE5,TE6,TE7	CONN, FEMALE 16-PIN	TE-118-10
TP1,TP2	CONN, TEST POINT	CS-553
U1	IC, VOLT. COMPARATOR, LM311M	IC-776
U12	IC, 8-CHAN ANA MULTIPLEXER, DG408DY	IC-844
U13,U23	IC, DUAL OPTO	IC-1358
U14,U15,U16,U17	IC, CENTIGRADE TEMP SENSOR LM35DM	IC-906
U18	IC, UNREGULATED DC/DC CONVERTER	IC-1355
U19,U20	IC, 16-BIT MONOLITHIC PCM AUDIO DAC	IC-1136
U2	IC, QUAD 2-INPUT NAND, 74HC00M	IC-781
U21,U22	IC, OPA177GS	IC-960
U24,U34	IC, TINYLOGIC CMOS INVERTER	IC-1282
U24,U34,U11,U26,U29,U7,U8,U9	IC, OCTAL D FLIP FLOP	IC-1353
U25	IC, -5V VOLTAGE REGULATOR	IC-1171
U3	IC, 8 STAGE SHIFT/STORE, MC14094BD	IC-772
U30,U31	IC, OCTAL BUFFER	IC-1252
U32	IC, 2.5V, CASCADABLE SERIAL EEPROM	LSI-212
U33	IC, 8-BIT MICROCONTROLLER	LSI-242
U4,U5	IC, SCHMITT-TRIGGER NAND GATE	IC-950
U6,U10	IC, 3-TO-8 LINE DECODE, 74ACT138	IC-654
VR1,VR2	DIODE ZENER 12V, MMSZ12T1	DZ-112
Y1	CRYSTAL CERAMIC RESONATOR, 8M	CR-59-2
MECHANICAL PARTS		
	TOP COVER HEAT STAKE ASSEMBLY	7700-302A
	BOTTOM CARD COVER	7702-301C
	COMPRESSION SPRING	SP-7-3

Figure D-26
Component layout
(Side-04)

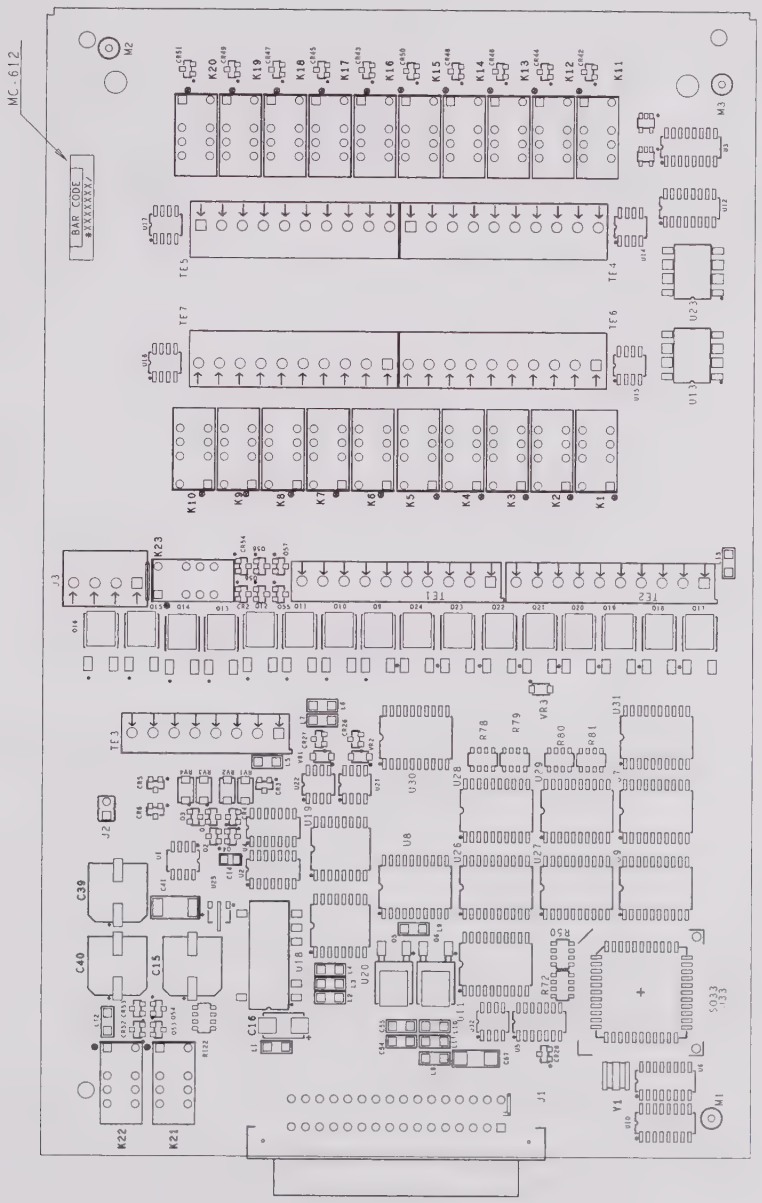
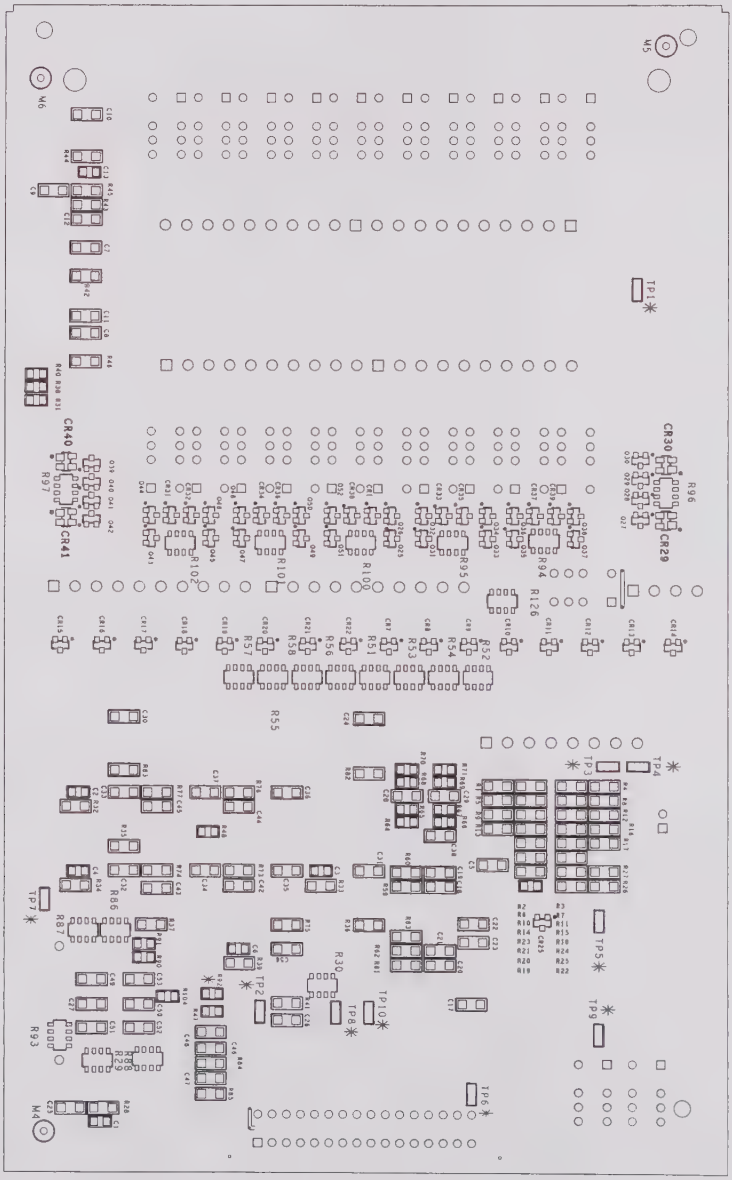


Figure D-27
Component layout (Side-01)



SECONDARY SIDE COMPONENTS (SIDE-01)

E
Status and Error Messages

Table E-1
Status and error messages

Number	Description	Event
-440	Query unterminated after indefinite response	EE
-430	Query deadlocked	EE
-420	Query unterminated	EE
-410	Query interrupted	EE
-363	Input buffer overrun	SYS
-350	Queue overflow	SYS
-330	Self-test failed	EE
-314	Save/recall memory lost	EE
-315	Configuration memory lost	EE
-285	Program syntax error	EE
-284	Program currently running	EE
-282	Illegal program name	EE
-281	Cannot create program	EE
-260	Expression error	EE
-241	Hardware missing	EE
-230	Data corrupt or stale	EE
-225	Out of memory	EE
-224	Illegal parameter value	EE
-223	Too much data	EE
-222	Parameter data out of range	EE
-221	Settings conflict	EE
-220	Parameter error	EE
-215	Arm deadlock	EE
-214	Trigger deadlock	EE
-213	Init ignored	EE
-212	Arm ignored	EE
-211	Trigger ignored	EE
-210	Trigger error	EE
-202	Settings lost due to rtl	EE
-201	Invalid while in local	EE
-200	Execution error	EE
-178	Expression data not allowed	EE
-171	Invalid expression	EE
-170	Expression error	EE
-168	Block data not allowed	EE
-161	Invalid block data	EE
-160	Block data error	EE
-158	String data not allowed	EE
-154	String too long	EE
-151	Invalid string data	EE
-150	String data error	EE

Table E-1 (Continued)
Status and error messages

Number	Description	Event
-148	Character data not allowed	EE
-144	Character data too long	EE
-141	Invalid character data	EE
-140	Character data error	EE
-128	Numeric data not allowed	EE
-124	Too many digits	EE
-123	Exponent too large	EE
-121	Invalid character in number	EE
-120	Numeric data error	EE
-114	Header suffix out of range	EE
-113	Undefined header	EE
-112	Program mnemonic too long	EE
-111	Header separator error	EE
-110	Command header error	EE
-109	Missing parameter	EE
-108	Parameter not allowed	EE
-105	GET not allowed	EE
-104	Data type error	EE
-103	Invalid separator	EE
-102	Syntax error	EE
-101	Invalid character	EE
-100	Command error	EE
+000	No error	SE
+101	Operation complete	SE
+121	Device calibrating	SE
+122	Device settling	SE
+123	Device ranging	SE
+124	Device sweeping	SE
+125	Device measuring	SE
+126	Device calculating	SE
+161	Program running	SE
+171	Waiting in trigger layer	SE
+174	Re-entering the idle layer	SE
+180	Filter settled	SE
+301	Reading overflow	SE
+302	Low limit 1 event	SE
+303	High limit 1 event	SE
+304	Low limit 2 event	SE
+305	High limit 2 event	SE
+306	Reading available	SE
+307	Voltmeter complete	SE

Table E-1 (Continued)
Status and error messages

Number	Description	Event
+308	Buffer available	SE
+309	Buffer half full	SE
+310	Buffer full	SE
+311	Buffer overflow	SE
+312	Buffer one quarter full	SE
+313	Buffer three quarters full	SE
+314	Master limit event	SE
	Calibration messages:	
+400	10vdc zero error	EE
+401	100vdc zero error	EE
+402	10vdc full scale error	EE
+403	-10vdc full scale error	EE
+404	100vdc full scale error	EE
+405	-100vdc full scale error	EE
+406	1k 2-w zero error	EE
+407	10k 2-w zero error	EE
+408	100k 2-w zero error	EE
+409	10M 2-w zero error	EE
+410	10M 2-w full scale error	EE
+411	10M 2-w open error	EE
+412	1k 4-w zero error	EE
+413	10k 4-w zero error	EE
+414	100k 4-w zero error	EE
+415	10M 4-w sense lo zero error	EE
+416	1k 4-w full scale error	EE
+417	10k 4-w full scale error	EE
+418	100k 4-w full scale error	EE
+419	1M 4-w full scale error	EE
+420	10M 4-w full scale error	EE
+421	10m adc zero error	EE
+422	100m adc zero error	EE
+423	10m adc full scale error	EE
+424	100m adc full scale error	EE
+425	1 adc full scale error	EE
+438	Date of calibration not set	EE
+439	Next date of calibration not set	EE
+450	100m vac dac error	EE
+451	1 vac dac error	EE
+452	10 vac dac error	EE
+453	100 vac dac error	EE
+454	100m vac zero error	EE
+455	100m vac full scale error	EE

Table E-1 (Continued)
Status and error messages

Number	Description	Event
+456	1 vac zero error	EE
+457	1 vac full scale error	EE
+458	1 vac noise error	EE
+459	10 vac zero error	EE
+460	10 vac full scale error	EE
+461	10 vac noise error	EE
+462	100 vac zero error	EE
+463	100 vac full scale error	EE
+464	750 vac zero error	EE
+465	750 vac full scale error	EE
+466	750 vac noise error	EE
+467	Post filter offset error	EE
+468	1 aac zero error	EE
+469	1 aac full scale error	EE
+470	3 aac zero error	EE
+471	3 aac full scale error	EE
+472	Input time constant error	EE
+473	Frequency gain error	EE
+474	1K Ohm loff Ocomp FS error	EE
+475	10K Ohm loff Ocomp FS error	EE
+476	Temperature Cold Cal error	EE
+477	Analog output zero error	EE
+478	Analog output pos. gain error	EE
+479	Analog output neg. gain error	EE
+500	Calibration data invalid	EE
+510	Reading buffer data lost	EE
+511	GPIB address lost	EE
+512	Power-on state lost	EE
+513	AC calibration data lost	EE
+514	DC calibration data lost	EE
+515	Calibration dates lost	EE
+516	Battery backed RAM error	EE
+517	Cannot resume scan	EE
+518	Card calibration data lost	EE
+519	Card calibration dates lost	EE
+520	Saved setup scancard mismatch	EE

Table E-1 (Continued)
Status and error messages

Number	Description	Event
+522	GPIB communication language lost	EE
+610	Questionable Calibration	SE
+611	Questionable Temperature	SE
+800	RS-232 Framing Error detected	EE
+802	RS-232 Overrun detected	EE
+803	RS-232 Break detected	EE
+805	Invalid system communication	EE
+808	ASCII only with RS-232	EE
+900	Internal System Error	EE
	DDC Status Model:	
+950	DDC Trigger Overrun Error	EE
+951	DDC Interval Overrun Error	EE
+952	DDC Big String Error	EE
+953	DDC Uncalibrated Error	EE
+954	DDC No Scanner Error	EE
+955	DDC Maximum Channel is 4	EE
+956	DDC Maximum Channel is 8	EE
+957	DDC Calibration Locked	EE
+958	DDC Conflict Error	EE
+959	DDC No Remote Error	EE
+960	DDC Mode IDDC Error	EE
+961	DDC Mode IDDCO Error	EE
	Keithley 199 Serial Poll Byte Events:	
+962	DDC Ready	SE
+963	DDC Reading Done	SE
+964	DDC Buffer Half Full	SE
+965	DDC Buffer Full	SE
+966	DDC Reading overflow	SE
	Fluke 8842 serial poll byte events:	
+970	Fluke Error	SE
+971	Data Available	SE
+972	Overrange	SE

EE = error event
SE = status event
SYS = system error event

NOTE *SCPI-confirmed messages are described in Volume 2: Command Reference of the Standard Commands for Programmable Instruments. Refer to the :SYSTem:ERRor? command.*

F
Measurement Considerations

Measurement considerations

Low-level voltage measurements made using the Model 2700 can be adversely affected by various types of noise or other unwanted signals that can make it very difficult to obtain accurate voltage readings. Some of the phenomena that can cause unwanted noise include thermoelectric effects (thermocouple action), source resistance noise, magnetic fields, and radio frequency interference. The following paragraphs discuss the most important of these effects and ways to minimize them.

NOTE *For comprehensive information on low-level measurements, see the "Low Level Measurements" handbook, which is available from Keithley.*

Thermoelectric potentials

Thermoelectric potentials (thermal EMFs) are small electric potentials generated by differences in temperature at the junction of dissimilar metals. The following paragraphs discuss how such thermals are generated and ways to minimize their effects.

Thermoelectric coefficients

As shown in Table F-1, the magnitude of thermal EMFs generated depends on the particular materials involved. Best results are obtained with clean copper-to-copper connections as indicated in the table.

Table F-1
Material thermoelectric coefficients

Material	Thermoelectric Potential
Copper-Copper	0.2µV/°C
Copper-Silver	0.3µV/°C
Copper-Gold	0.3µV/°C
Copper-Cadmium/Tin	0.3µV/°C
Copper-Lead/Tin	1–3µV/°C
Copper-Kovar	40µV/°C
Copper-Silicon	400µV/°C
Copper-Copper Oxide	1000µV/°C

Thermoelectric generation

Figure F-1 shows a representation of how thermal EMFs are generated. The test leads are made of the A material, while the source under test is the B material. The temperatures between the junctions are shown as T_1 and T_2. To determine the thermal EMF generated, the following relationship may be used:

$$E_T = Q_{AB} (T_1 - T_2)$$

where: E_T = Generated thermal EMF
Q_{AB} = Thermoelectric coefficient of material A with respect to material B (μV/°C)
T_1 = Temperature of B junction (°C or K)
T_2 = Temperature of A junction (°C or K)

In the unlikely event that the two junction temperatures are identical, no thermal EMFs will be generated. More often, the two junction temperatures will differ, and considerable thermal EMFs will be generated.

A typical test setup will probably have several copper-to-copper junctions. As pointed out earlier, each junction can have a thermoelectric coefficient as high as 0.2μV/°C. Since the two materials will frequently have a several degree temperature differential, it is easy to see how thermal potentials of several microvolts can be generated even if reasonable precautions are taken.

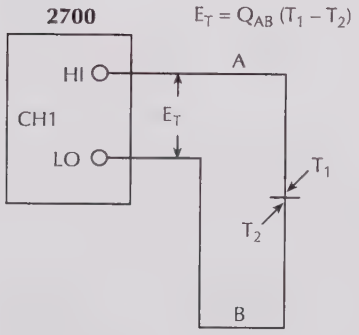


Figure F-1
Thermal EMF generation

Minimizing thermal EMFs

To minimize thermal EMFs, use only copper wires, lugs, and test leads for the entire test setup. Also, it is imperative that all connecting surfaces are kept clean and free of oxides. As noted in Table F-1, copper-to-copper oxide junctions can result in thermal EMFs as high as 1mV/°C.

Even when low-thermal cables and connections are used, thermal EMFs can still be a problem in some cases. It is especially important to keep the two materials forming the junction at the same temperature. Keeping the two junctions close together is one way to minimize such thermal problems. Also, keep all junctions away from air currents; in some cases, it may be necessary to thermally insulate sensitive junctions to minimize temperature variations. When a Cu–Cu connection is made, sufficient pressure must be applied to ensure the connection is gas tight to prevent future oxidation.

In some cases, connecting the two thermal junctions together with good thermal contact to a common heat sink may be required. Unfortunately, most good electrical insulators are poor conductors of heat. In cases where such low thermal conductivity may be a problem, special insulators that combine high electrical insulating properties with high thermal conductivity may be used. Some examples of these materials include hard anodized aluminum, sapphire, and diamond.

Nulling residual thermal offsets

Even if all reasonable precautions are taken, some residual thermal offsets may still be present. These offsets can be minimized by using the Model 2700 Relative feature to null them out. To do so, place the instrument on the 3mV range and short the end of the connecting cable nearest the measured source (first disconnect the cable from the source to avoid shorting out the source). After allowing the reading to settle, press the front panel REL button to null the offset. Select the appropriate range, and make your measurement as usual.

If the offset voltage varies, the DC current-reversal technique should be used instead of REL. The DC current-reversal technique requires a source that can output currents equal in magnitude but opposite in polarity. In general, a voltage measurement is performed on both the positive and negative alternations of the current source. The averaged difference of those two readings cancels the thermal EMF component of the measurements. The Model 2700 can automatically perform the measurements and calculate and display the result by using the Delta measurement mode. See "Delta" in Section 5 for details.

Source resistance noise

Noise present in the source resistance is often the limiting factor in the ultimate resolution and accuracy of Model 2700 measurements. The paragraphs below discuss the generation of Johnson noise as well as ways to minimize such noise.

Johnson noise equation

The amount of noise present in a given resistance is defined by the Johnson noise equation as follows:

$$E_{RMS} = \sqrt{4kTRF}$$

where: E_{RMS} = rms value of the noise voltage
k = Boltzmann's constant (1.38×10^{-23}J/K)
T = Temperature (K)
R = Source resistance (ohms)
F = Noise bandwidth (Hz)

At a room temperature of 293K (20°C), the above equation simplifies to:

$$E_{RMS} = 1.27 \times 10^{-10}\sqrt{RF}$$

Since the peak to peak noise is five times the rms value 99% of the time, the peak to peak noise can be equated as follows:

$$E_{p-p} = 6.35 \times 10^{-10}\sqrt{RF}$$

For example, with a source resistance of 10kΩ, the noise over a 0.5Hz bandwidth at room temperature will be:

$$E_{p-p} = 6.35 \times 10^{-10}\sqrt{(10 \times 10^{3})(0.5)}$$

$$E_{p-p} = 45\text{nV}$$

Minimizing source resistance noise

From the above examples, it is obvious that noise can be reduced in several ways: (1) lower the temperature, (2) reduce the source resistance, and (3) narrow the bandwidth. Of these three, lowering the resistance is the least practical because the signal voltage will be reduced more than the noise. For example, decreasing the resistance of a current shunt by a factor of 100 will also reduce the voltage by a factor of 100, but the noise will be decreased only by a factor of 10.

Very often, cooling the source is the only practical method available to reduce noise. Again, however, the available reduction is not as large as it might seem because the reduction is related to the square root of the change in temperature. For example, to cut the noise in half, the temperature must be decreased from 293K to 73.25K, a four-fold decrease.

Magnetic fields

When a conductor loop cuts through magnetic lines of force, a very small current is generated. This phenomenon will frequently cause unwanted signals to occur in the test leads of a test system. If the conductor has sufficient length or cross-sectional area, even weak magnetic fields such as those of the earth can create sufficient signals to affect low-level measurements.

Three ways to reduce these effects are: (1) reduce the lengths of the connecting cables, (2) minimize the exposed circuit area, and (3) change the orientation of the leads or cables. In extreme cases, magnetic shielding may be required. Special metal with high permeability at low flux densities (such as mu metal) are effective at reducing these effects.

Even when the conductor is stationary, magnetically-induced signals may still be a problem. Fields can be produced by various sources such as the AC power line voltage. Large inductors such as power transformers can generate substantial magnetic fields, so care must be taken to keep the Model 2700 voltage source and connecting cables a good distance away from these potential noise sources.

Radio frequency interference

RFI (Radio Frequency Interference) is a general term used to describe electromagnetic interference over a wide range of frequencies across the spectrum. Such RFI can be particularly troublesome at low signal levels, but it can also affect measurements at high levels if the fields are of sufficient magnitude.

RFI can be caused by steady-state sources such as radio or TV signals, or some types of electronic equipment (microprocessors, high speed digital circuits, etc.), or it can result from impulse sources, as in the case of arcing in high-voltage environments. In either case, the effect on the measurement can be considerable if enough of the unwanted signal is present.

RFI can be minimized in several ways. The most obvious method is to keep the Model 2700 voltage source and signal leads as far away from the RFI source as possible. Additional shielding of the instrument, signal leads, sources, and other measuring instruments will often reduce RFI to an acceptable level. In extreme cases, a specially-constructed screen room may be required to sufficiently attenuate the troublesome signal.

The Model 2700 digital filter may help to reduce RFI effects in some situations. In some cases, additional external filtering may also be required. Keep in mind, however, that filtering may have detrimental effects such as increased settling time on the desired signal.

Ground loops

When two or more instruments are connected together, care must be taken to avoid unwanted signals caused by ground loops. Ground loops usually occur when sensitive instrumentation is connected to other instrumentation with more than one signal return path such as power line ground. As shown in Figure F-2, the resulting ground loop causes current to flow through the instrument LO signal leads and then back through power line ground. This circulating current develops a small but undesirable voltage between the LO terminals of the two instruments. This voltage will be added to the source voltage, affecting the accuracy of the measurement.

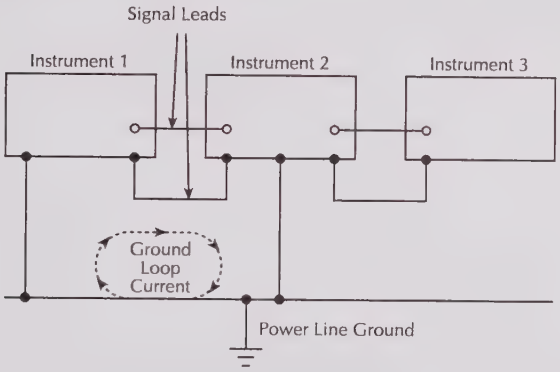
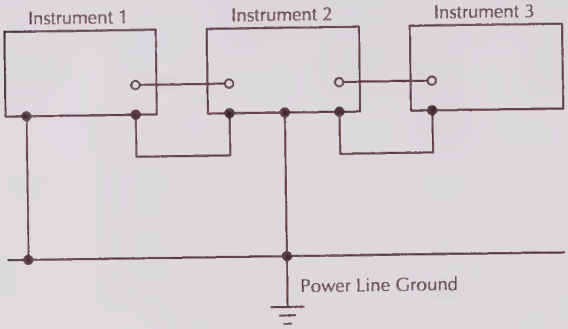


Figure F-2
Power line ground loops

Figure F-3 shows how to connect several instruments together to eliminate this type of ground loop problem. Here, only one instrument is connected to power line ground.

Ground loops are not normally a problem with instruments like the Model 2700 that have isolated LO terminals. However, all instruments in the test setup may not be designed in this manner. When in doubt, consult the manual for all instrumentation in the test setup.

Figure F-3
Eliminating ground loops



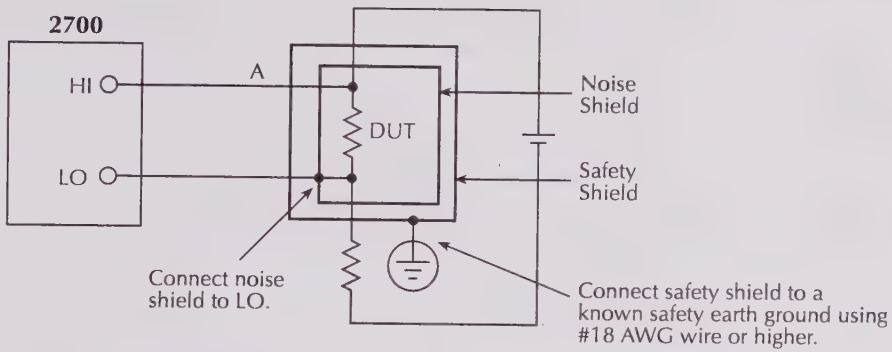
Shielding

Proper shielding of all signal paths and sources being measured is important to minimize noise pickup in virtually any low-level measurement situation. Otherwise, interference from such noise sources as line frequency and RF fields can seriously corrupt measurements, rendering experimental data virtually useless.

In order to minimize noise, a closed metal shield surrounding the source may be necessary, as shown in the example of Figure F-4. This shield should be connected to input LO in most cases, although better noise performance may result with the shield connected to chassis ground in some situations.

WARNING **Do not float input LO more than 30V rms, 42.4V peak above earth ground with an exposed shield connected to input LO. To avoid a possible shock hazard, surround the LO shield with a second safety shield that is insulated from the inner shield. Connect this safety shield to safety earth ground using #18 AWG minimum wire before use.**

Figure F-4
Shielding example



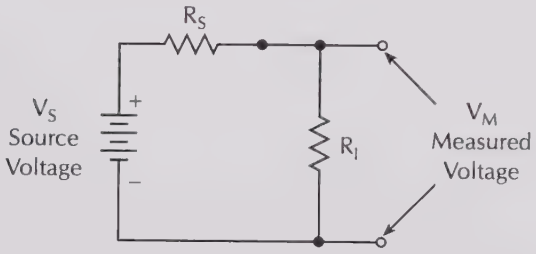
WARNING: Safety shield required when floating noise shield >30V rms above chassis ground.

Meter loading

Loading of the voltage source by the Model 2700 becomes a consideration for high source resistance values. As the source resistance increases, the error caused by meter loading increases.

Figure F-5 shows the method used to determine the percent error due to meter loading. The voltage source, V_S, has a source resistance, R_S, while the input resistance of the Model 2700 is R_I, and the voltage measured by the nanovoltmeter is V_M.

Figure F-5
Meter loading



The voltage actually measured by the meter is attenuated by the voltage divider action of R_S and R_I, and it can be calculated as follows:

$$V_M = \frac{V_S R_L}{R_I + R_S}$$

This relationship can be modified to directly compute for percent error:

$$\text{Percent error} = \frac{100 R_S}{R_I + R_S}$$

From the above equation, it is obvious that the input resistance of the Model 2700 must be at least 999 times the value of source resistance if loading error is to be kept to within 0.1%.

G
IEEE-488 Bus Overview

Introduction

The IEEE-488 bus is a communication system between two or more electronic devices. A device can be either an instrument or a computer. When a computer is used on the bus, it serves as a supervisor of the communication exchange between all the devices and is known as the controller. Supervision by the controller consists of determining which device will talk and which device will listen. As a talker, a device will output information and as a listener, a device will receive information. To simplify the task of keeping track of the devices, a unique address number is assigned to each.

On the bus, only one device can talk at a time and is addressed to talk by the controller. The device that is talking is known as the active talker. The devices that need to listen to the talker are addressed to listen by the controller. Each listener is then referred to as an active listener. Devices that do not need to listen are instructed to unlisten. The reason for the unlisten instruction is to optimize the speed of bus information transfer since the task of listening takes up bus time.

Through the use of control lines, a handshake sequence takes place in the transfer process of information from a talker to a listener. This handshake sequence helps ensure the credibility of the information transfer. The basic handshake sequence between an active controller (talker) and a listener is as follows:

1. The listener indicates that it is ready to listen.
2. The talker places the byte of data on the bus and indicates that the data is available to the listener.
3. The listener, aware that the data is available, accepts the data and then indicates that the data has been accepted.
4. The talker, aware that the data has been accepted, stops sending data and indicates that data is not being sent.
5. The listener, aware that there is no data on the bus, indicates that it is ready for the next byte of data.

Bus description

The IEEE-488 bus, which is also referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines.

A typical setup for controlled operation is shown in Figure G-1. Generally, a system will contain one controller and a number of other instruments to which the commands are given. Device operation is categorized into three operators: controller, talker, and listener. The controller controls the instruments on the bus. The talker sends data while a listener receives data. Depending on the type of instrument, any particular device can be a talker only, a listener only, or both a talker and listener.

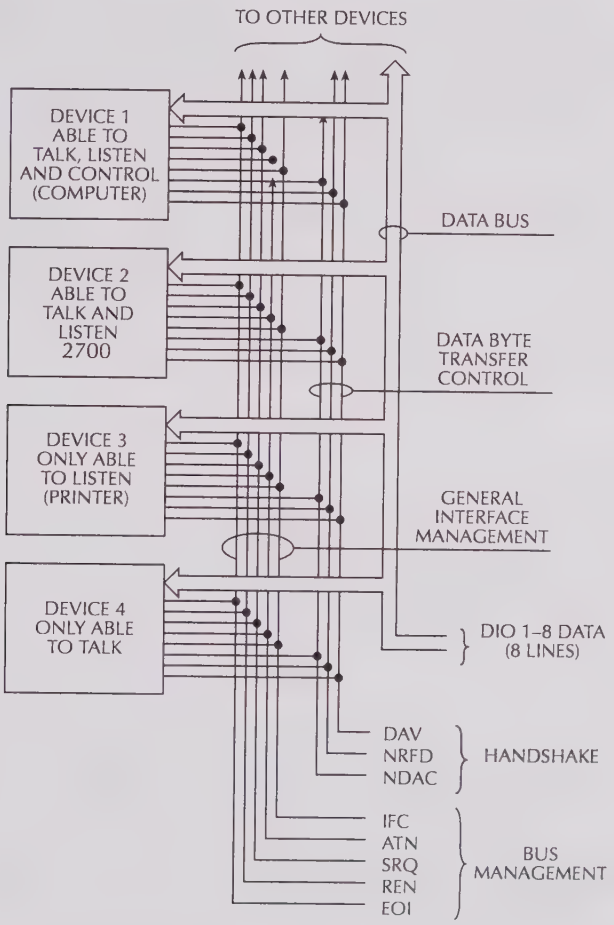


Figure G-1
IEEE-488 bus configuration

There are two categories of controllers: system controller and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 31, and is generally set by rear panel DIP

switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with $20. For example, if the primary address is $7, the actual listen address is $27 ($27 = $7 + $20). In a similar manner, the talk address is obtained by ORing the primary address with $40. With the present example, the talk address derived from a primary address of $7 would be $47 ($47 = $7 + $40).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of $60-$7F. Note, however, that many devices, including the Model 2700, do not use secondary addressing.

Once a device is addressed to talk or listen, the appropriate bus transactions take place. For example, if the instrument is addressed to talk, it places its data string on the bus one byte at a time. The controller reads the information, and the appropriate software can be used to direct the information to the desired location.

Bus lines

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines, and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the operation of these lines.

Data lines

The IEEE-488 bus uses eight data lines that transfer data one byte at a time. DIO1 (Data Input/Output) through DIO8 (Data Input/Output) are the eight data lines used to transmit both data and multiline commands and are bi-directional. The data lines operate with low true logic.

Bus management lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands.

ATN (Attention) — The ATN state determines how information on the data bus is to be interpreted.

IFC (Interface Clear) — The IFC line controls clearing of instruments from the bus.

REN (Remote Enable) —The REN line is used to place the instrument on the bus in the remote mode.

EOI (End or Identify) — The EOI line is used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request) — The SRQ line is used by devices when they require service from the controller.

Handshake lines

The bus handshake lines operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (DATA VALID) — The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

NRFD (Not Ready For Data) — The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence until the accepting device is ready.

NDAC (Not Data Accepted) — NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

The complete handshake sequence for one data byte is shown in Figure G-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100ns after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

The previous sequence is used to transfer both data, talk and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses, or commands as described in the following paragraphs.

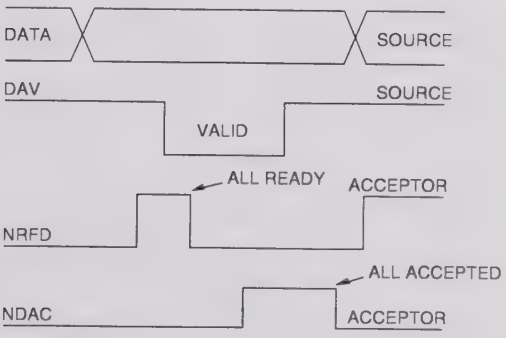


Figure G-2
IEEE-488 handshake sequence

Bus commands

The instrument may be given a number of special bus commands through the IEEE-488 interface. The following paragraphs briefly describe the purpose of the bus commands which are grouped into the following four categories.

1. Uniline commands — Sent by setting the associated bus lines true. For example, to assert REN (Remote Enable), the REN line would be set low (true).
2. Multiline commands — General bus commands which are sent over the data lines with the ATN line true (low).
3. Common commands — Commands that are common to all devices on the bus; sent with ATN high (false).
4. SCPI commands — Commands that are particular to each device on the bus; sent with ATN (false).

These bus commands and their general purpose are summarized in Table G-1.

Table G-1
IEEE-488 bus command summary

Command type	Command	State of ATN line	Comments
Uniline	REN (Remote Enable)	X	Set up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from the bus.
	UNT (Untalk)	Low	Removes any talkers from the bus.
Common	—	High	Programs IEEE-488.2 compatible instruments for common operations.
SCPI	—	High	Programs SCPI compatible instruments for particular operations.

Uniline commands

ATN, IFC and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a description of each command. Each command is sent by setting the corresponding bus line true.

REN (Remote Enable) — REN is sent to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be sent before attempting to program instruments over the bus.

EOI (End or Identify) — EOI is used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.

IFC (Interface Clear) — IFC is used to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention) — The controller sends ATN while transmitting addresses or multiline commands.

SRQ (Service Request) — SRQ is asserted by a device when it requires service from a controller.

Universal multiline commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout) — LLO is sent to the instrument to lock out the LOCAL key and all their front panel controls.

DCL (Device Clear) — DCL is used to return instruments to some default state. Instruments usually return to their power-up conditions.

SPE (Serial Poll Enable) — SPE is the first step in the serial polling sequence which is used to determine which device has requested service.

SPD (Serial Poll Disable) — SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

Addressed multiline commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands. Both the commands and the address preceding it are sent with ATN true.

SDC (Selective Device Clear) — The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local) — The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger) — The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

Address commands

Addressed commands include two primary command groups and a secondary address group. ATN is true when these commands are asserted. The commands include:

LAG (Listen Address Group) — These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group) — The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group) — Commands in this group provide additional addressing capabilities. Many devices (including the Model 2700) do not use these commands.

Unaddress commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten) — Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk) — Any previously commanded talkers will be placed in the talker idle state by the UNT command.

Common commands

Common commands are commands that are common to all devices on the bus. These commands are designated and defined by the IEEE-488.2 standard.

Generally, these commands are sent as one or more ASCII characters that tell the device to perform a common operation, such as reset. The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

SCPI commands

SCPI commands are commands that are particular to each device on the bus. These commands are designated by the instrument manufacturer and are based on the instrument model defined by the Standard Commands for Programmable Instruments (SCPI) Consortium's SCPI standard.

Generally, these commands are sent as one or more ASCII characters that tell the device to perform a particular operation, such as setting a range or closing a relay. The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command codes

Command codes for the various commands that use the data lines are summarized in Figure G-3. Hexadecimal and the decimal values for the various commands are listed in Table G-2.

Table G-2
Hexadecimal and decimal command codes

Command	Hex value	Decimal value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SCG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Figure G-3
Command codes

D_7 D_6 D_5 D_4						X 0 0 0	Command	X 0 0 1	Command	X 0 1 0	Primary Address	X 0 1 1	Primary Address	X 1 0 0	Primary Address	X 1 0 1	Primary Address	X 1 1 0		X 1 1 1	
Bits	D_3 ↓	D_2 ↓	D_1 ↓	D_0 ↓	Column→ Row ↓	0 (A)	0 (B)	1 (A)	1 (B)	2 (A)	2 (B)	3 (A)	3(B)	4 (A)	4 (B)	5 (A)	5 (B)	6 (A)	6 (B)	7 (A)	7 (B)
	0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
	0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
	0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
	0	0	1	1	3	ETX		DC3		#	3	3	19	C	3	S	19	c		s	
	0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
	0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
	0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
	0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
	1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
	1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
	1	0	1	0	10	LF		SUB		•	10	:	26	J	10	Z	26	j		z	
	1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
	1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
	1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
	1	1	1	0	14	SO		RS		.	14	>	30	N	14	∩	30	n		≅	
	1	1	1	1	15	SI		US		/	15	?	UNL	O	15	—	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE) PPU (PARALLEL POLL UNCONFIGURE), and TCT (TAKE CONTROL) not implemented by Model 2700.

Note: D_0 = DIO1 ... D_7 = DIO8; X = Don't Care.

Typical command sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table G-3 lists a typical bus sequence for sending the addressed multiline commands. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table G-3
Typical addressed command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	'	27	39
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 7.

Table G-4 gives a typical common command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the common command string.

Table G-4
Typical addressed command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	'	27	39
3	Data	Set high	*	2A	42
4	Data	Stays high	R	52	82
5	Data	Stays high	S	53	83
6	Data	Stays high	T	54	84

*Assumes primary address = 7.

IEEE command groups

Command groups supported by the Model 2700 are listed in Table G-5. Common commands and SCPI commands are not included in this list.

Table G-5
IEEE command groups

HANDSHAKE COMMAND GROUP	
	NDAC = NOT DATA ACCEPTED
	NRFD = NOT READY FOR DATA
	DAV = DATA VALID
UNIVERSAL COMMAND GROUP	
	ATN = ATTENTION
	DCL = DEVICE CLEAR
	IFC = INTERFACE CLEAR
	REN = REMOTE ENABLE
	SPD = SERIAL POLL DISABLE
	SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP	
LISTEN	LAG = LISTEN ADDRESS GROUP
	MLA = MY LISTEN ADDRESS
	UNL = UNLISTEN
TALK	TAG = TALK ADDRESS GROUP
	MTA = MY TALK ADDRESS
	UNT = UNTALK
	OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP	
	ACG = ADDRESSED COMMAND GROUP
	GTL = GO TO LOCAL
	SDC = SELECTIVE DEVICE CLEAR
STATUS COMMAND GROUP	
	RQS = REQUEST SERVICE
	SRQ = SERIAL POLL REQUEST
	STB = STATUS BYTE
	EOI = END

Interface function codes

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual. The interface function codes for the Model 2700 are listed in Table G-6.

Table G-6
Model 2700 interface function codes

Code	Interface function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability
T5	Talker (basic talker, talk-only, serial poll, unaddressed to talk on LAG)
L4	Listener (basic listener, unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open collector bus drivers
TE0	No Extended Talker capability
LE0	No Extended Listener capability

The codes define Model 2700 capabilities as follows:

SH (Source Handshake Function) — SH1 defines the ability of the instrument to initiate the transfer of message/data over the data bus.

AH (Acceptor Handshake Function) — AH1 defines the ability of the instrument to guarantee proper reception of message/data transmitted over the data bus.

T (Talker Function) — The ability of the instrument to send data over the bus to other devices is provided by the T function. Instrument talker capabilities (T5) exist only after the instrument has been addressed to talk.

L (Listener Function) — The ability for the instrument to receive device-dependent data over the bus from other devices is provided by the L function. Listener capabilities (L4) of the instrument exist only after it has been addressed to listen.

SR (Service Request Function) — SR1 defines the ability of the instrument to request service from the controller.

RL (Remote-Local Function) — RL1 defines the ability of the instrument to be placed in the remote or local modes.

PP (Parallel Poll Function) — The instrument does not have parallel polling capabilities (PP0).

DC (Device Clear Function) — DC1 defines the ability of the instrument to be cleared (initialized).

DT (Device Trigger Function) — DTI defines the ability of the Model 2700 to have readings triggered.

C (Controller Function) — The instrument does not have controller capabilities (C0).

TE (Extended Talker Function) — The instrument does not have extended talker capabilities (TE0).

LE (Extended Listener Function) — The instrument does not have extended listener capabilities (LE0).

E (Bus Driver Type) — The instrument has open-collector bus drivers (E1).

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Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

❑ Intermittent ❑ Analog output follows display ❑ Particular range or function bad; specify

_____

❑ IEEE failure ❑ Obvious problem on power-up ❑ Batteries and fuses are OK

❑ Front panel operational ❑ All ranges or functions are bad ❑ Checked all cables

Display or output (check one)

❑ Drifts ❑ Unable to zero ❑ Unstable

❑ Overload ❑ Will not read applied input

❑ Calibration only ❑ Certificate of calibration required ❑ Data required

(attach any additional sheets as necessary)

Show a block diagram of your measurement including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

_____

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

Keithley Instruments, Inc.
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Cleveland, Ohio 44139
www.keithley.com

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